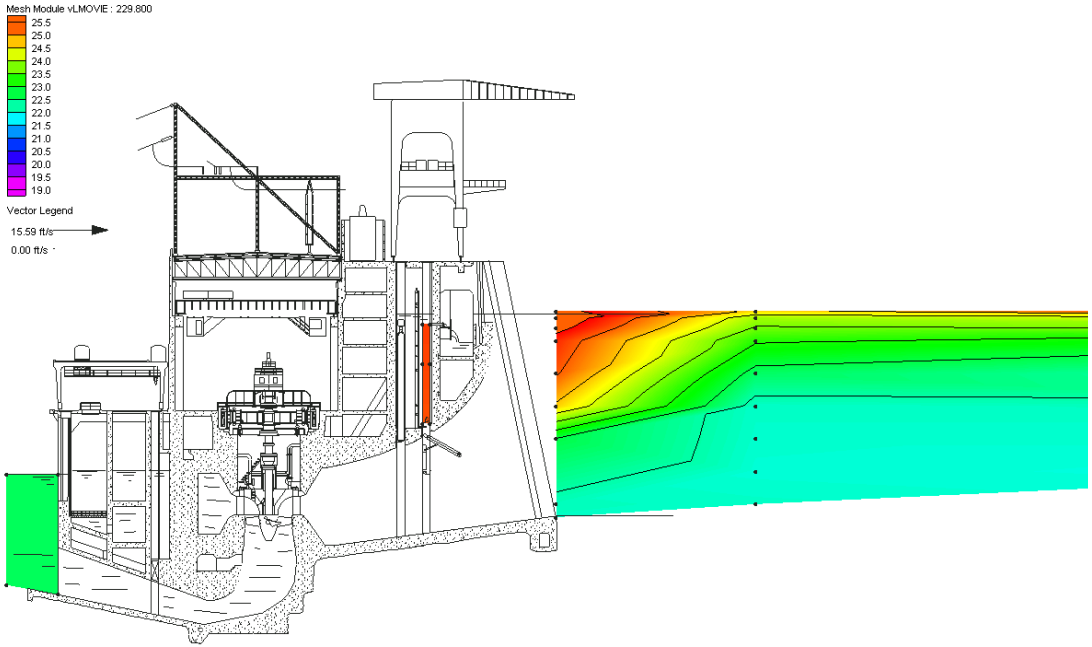
McNary Dam & Forebay Thermal Characterization 2004



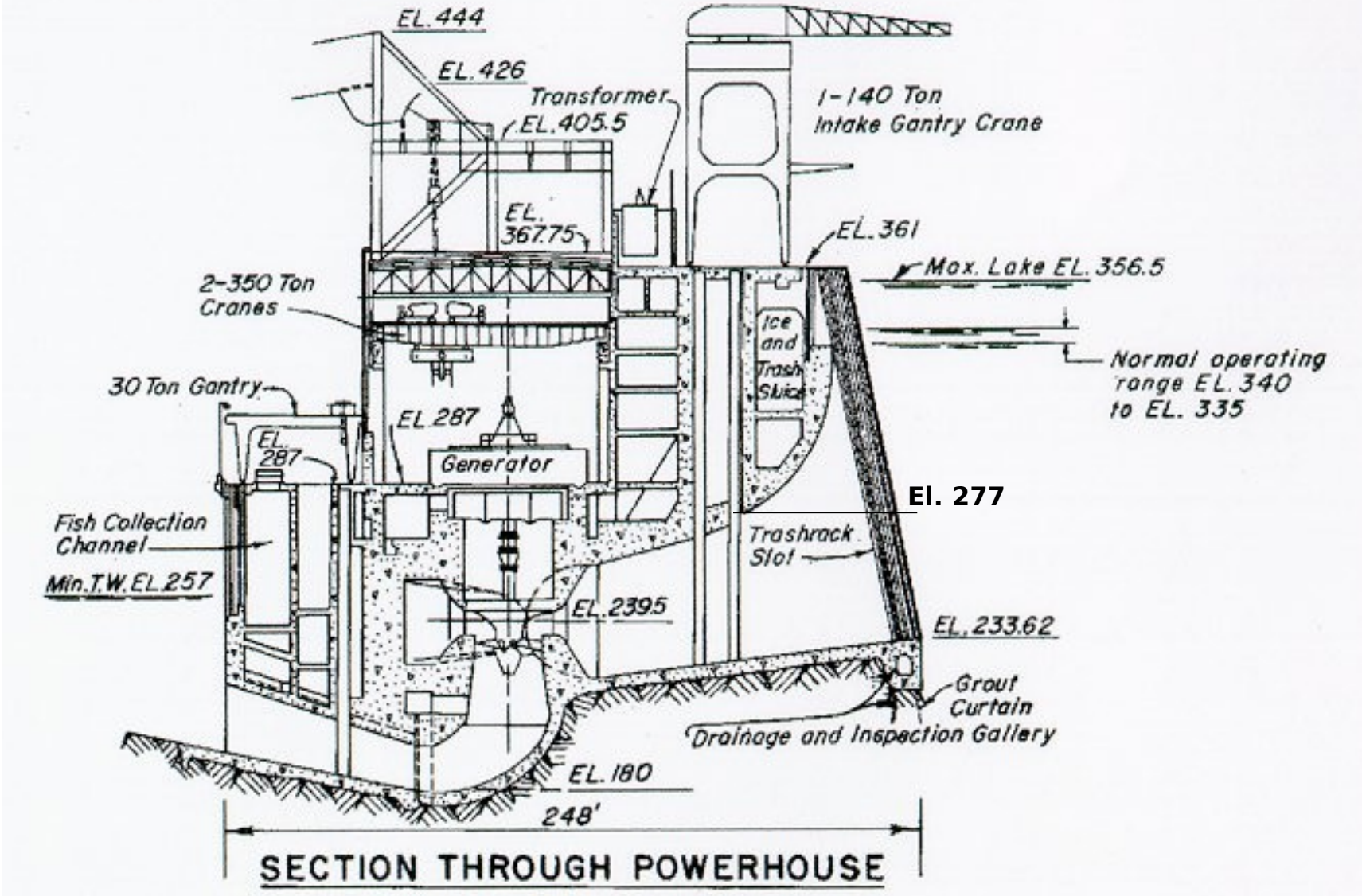
Walla Walla District April 11, 2005

McNary Dam & Forebay Thermal Characterization 2004

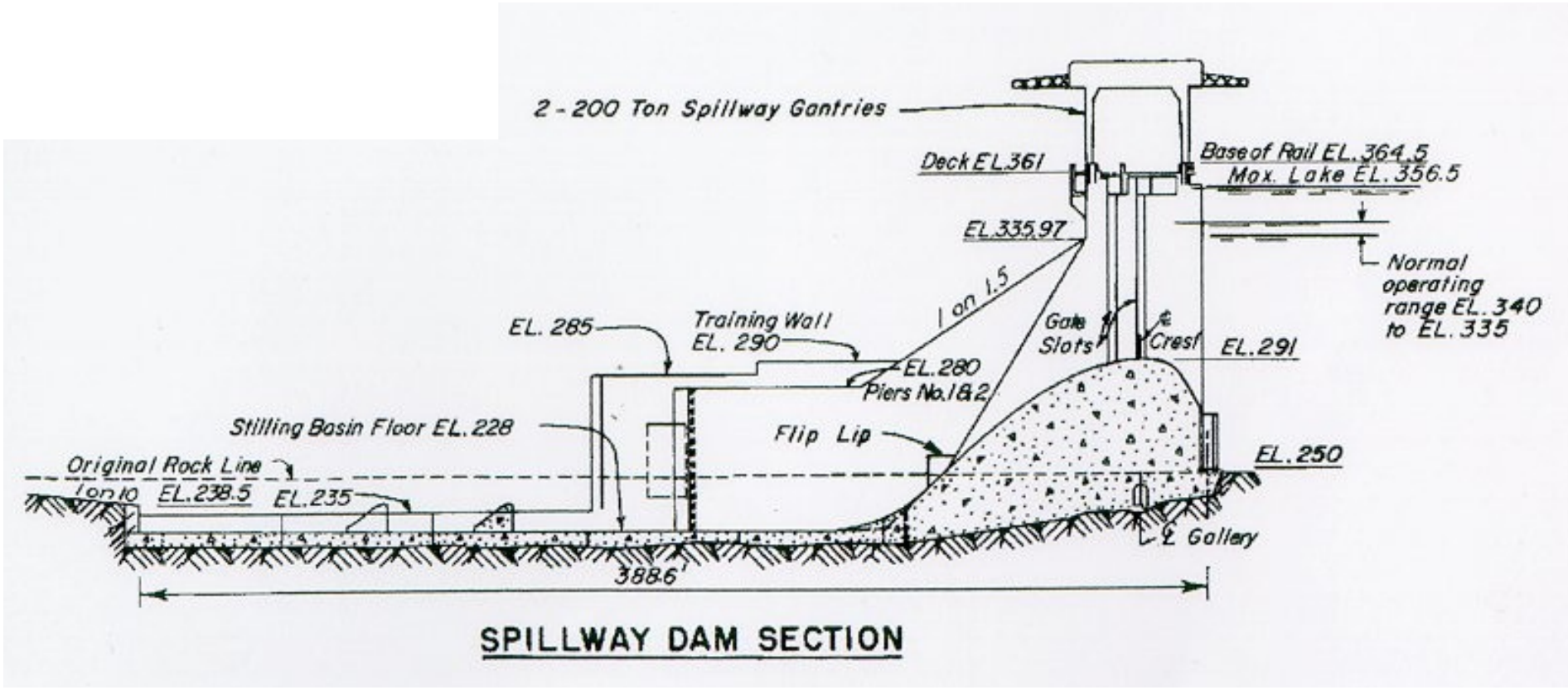
- Introduction
  - 2004 Field data collected to support 3D CFD model
    - Hydrodynamics
    - Heat Exchange and Transport
  - Data Analyses complementary to modeling study
    - Temporal
    - Spatial
    - Quantify thermal response to wide range met/operations
- Background
  - Thermal patterns investigated since 1987 WDFW
    - 1998 detailed 24 sampling
  - Numerous thermal/biological investigations
  - USGS mixers 2002

McNary Dam & Forebay Thermal Characterization 2004

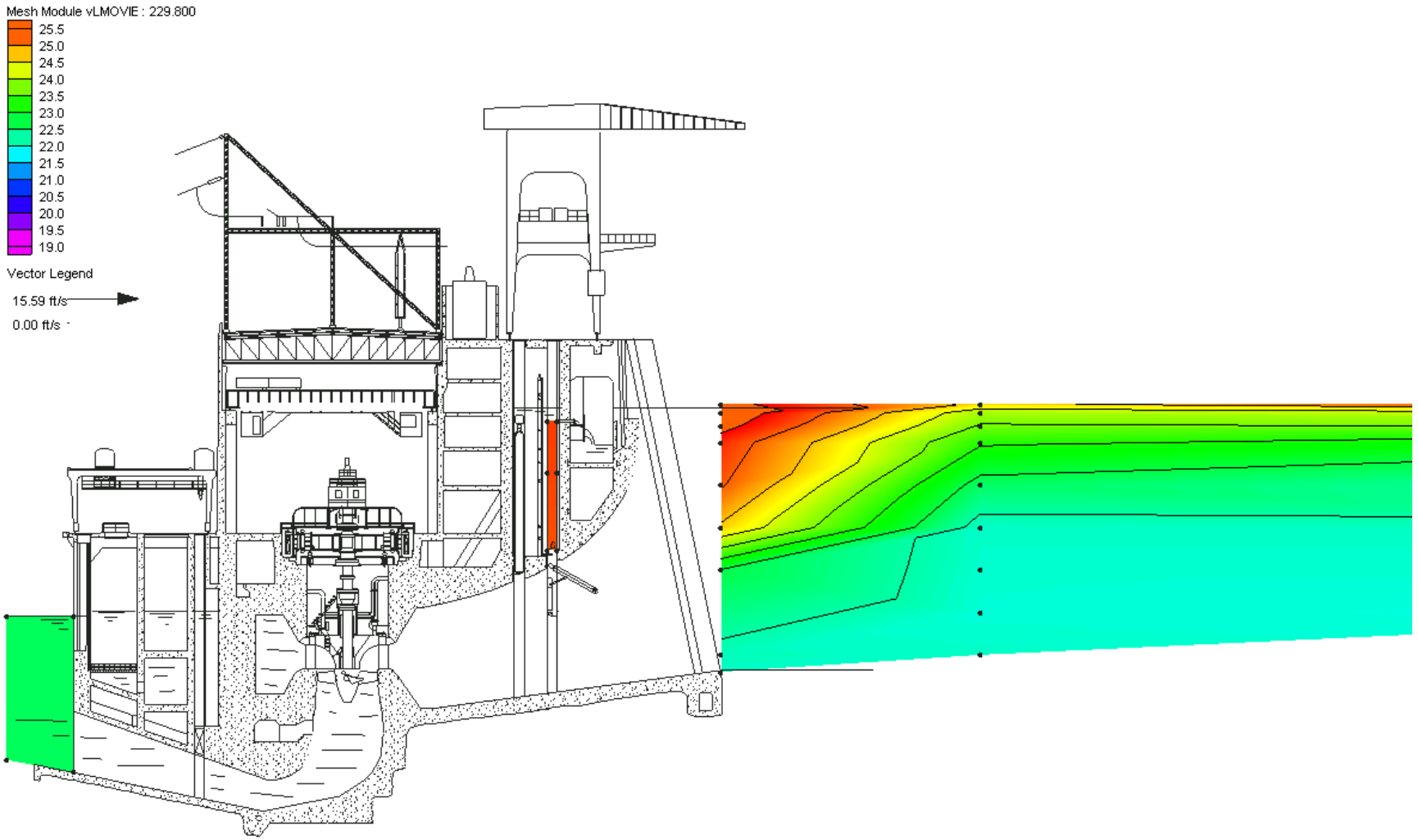
- Objectives
  - Characterize water temperature response in CR at McNary Dam
    - Forebay Patterns
    - In-structure response
    - Temp released to tailwater
  - Tasks
    - Database development
      - Operations, Meteorologic, Flow Field, Bathymetry, Temperature
    - Data Analyses and presentation
    - Summary documentation



McNary Dam Powerhouse Section

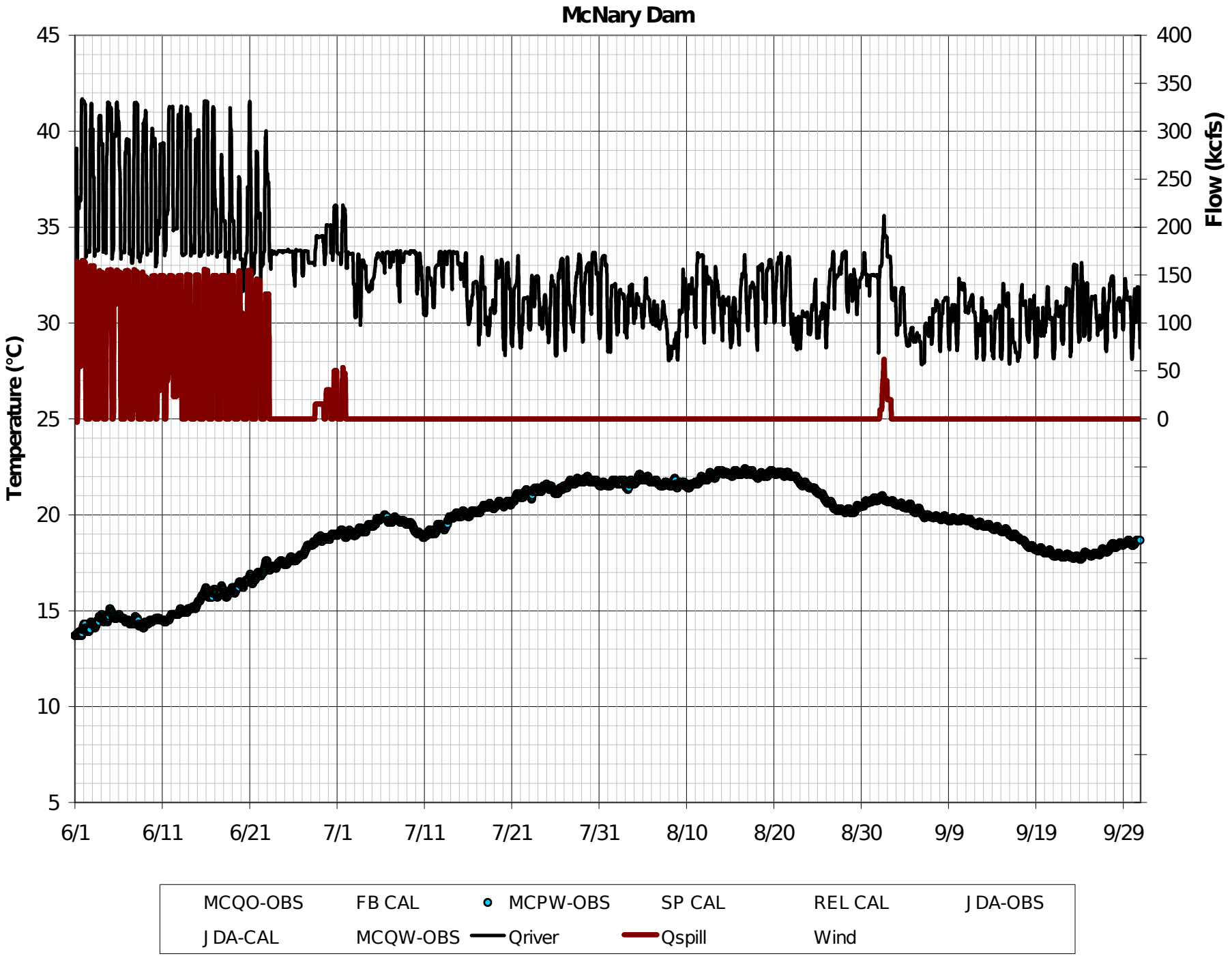


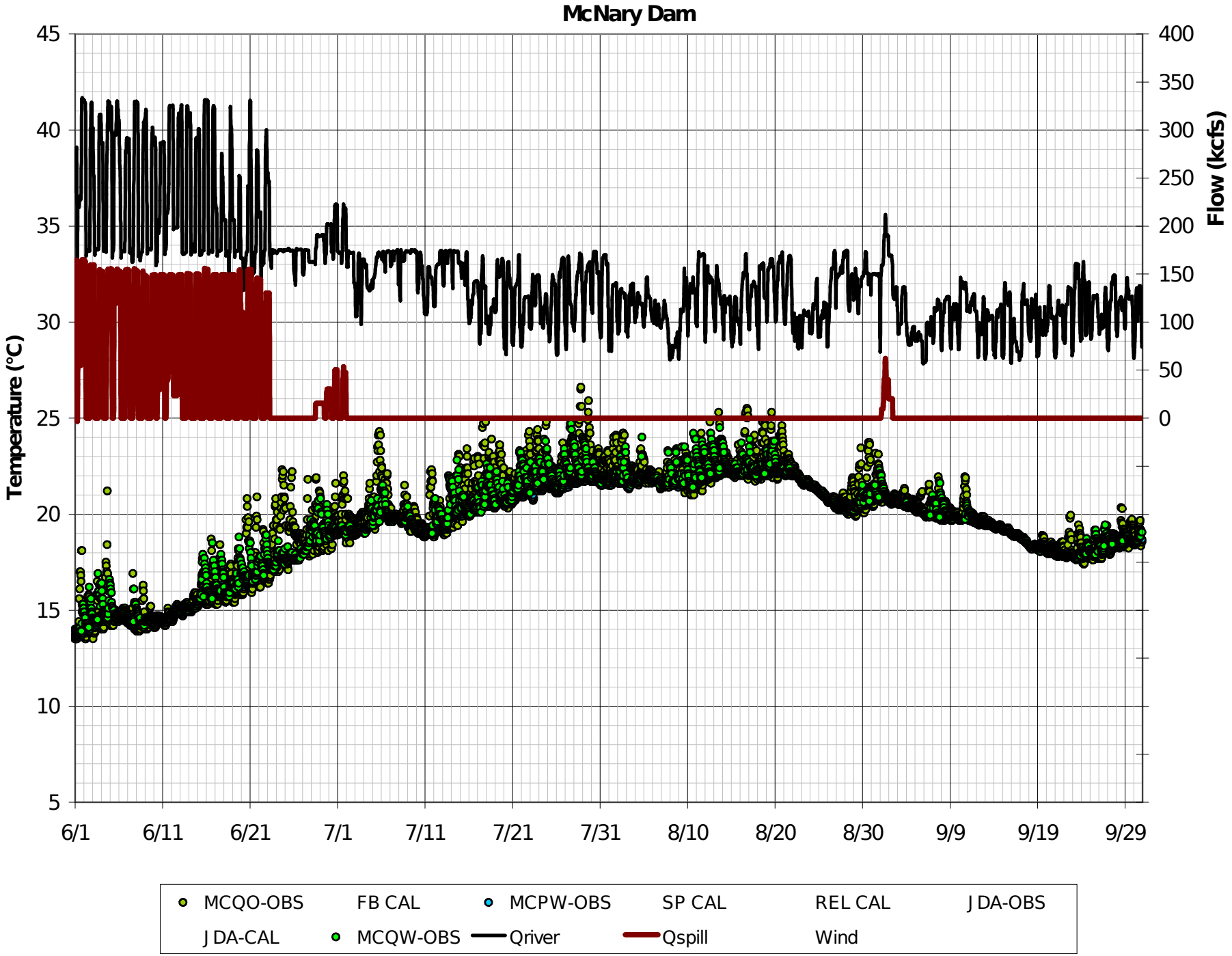
SPILLWAY DAM SECTION

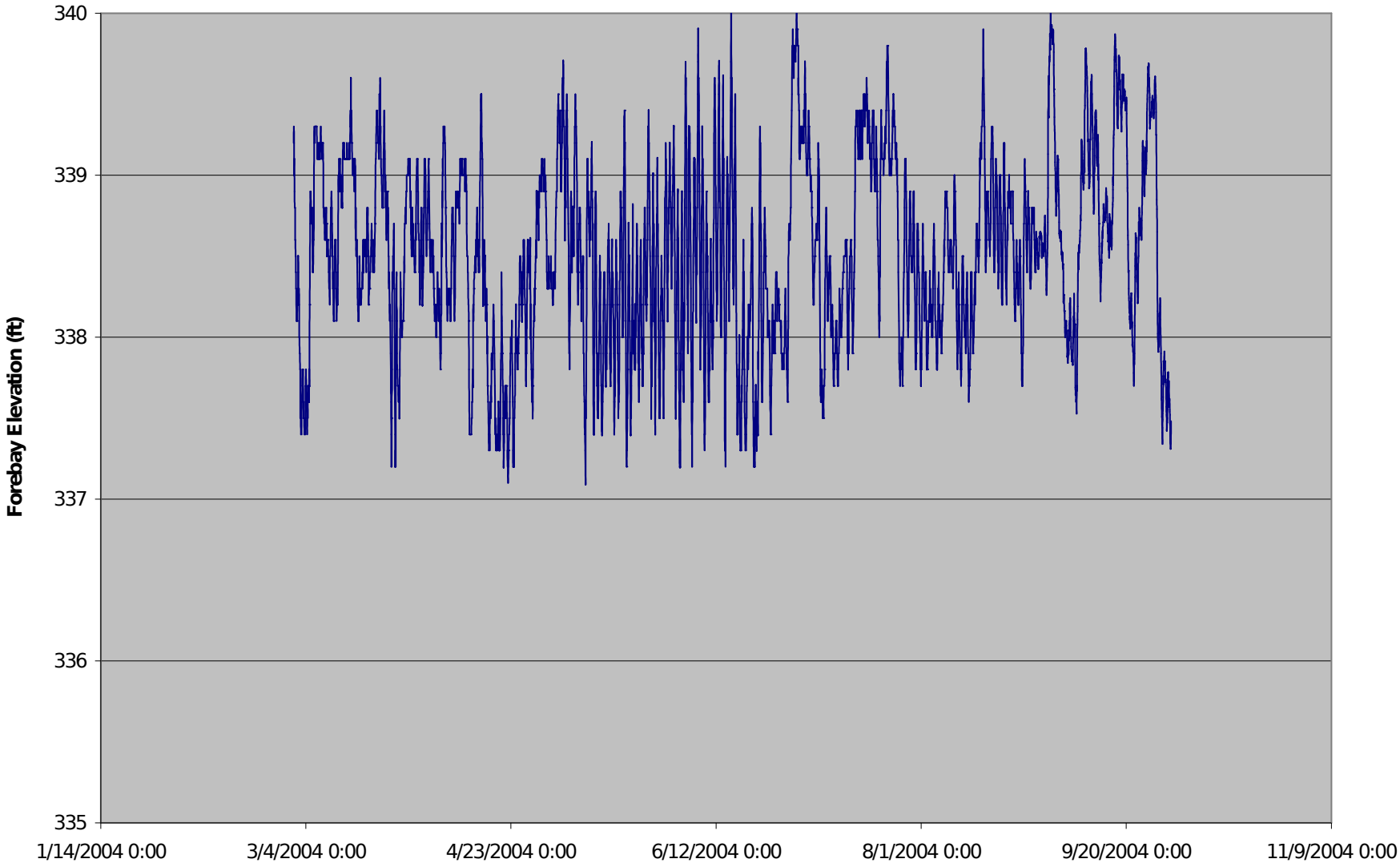

Mesh Module vLMOVIE : 229.800
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
19.5
19.0
Vector Legend
15.59 ft/s
0.00 ft/s

McNary Dam & Forebay Thermal Characterization 2004

- Operations
  - Turbine Discharge Range (1% best efficiency)
    - 7.9 - 12.3 kcfs (~170 kcfs hydraulic capacity)
  - Unit Priority (north side during warm water conditions)
  - Spill versus Transportation
    - Spring Like Conditions 62 F
  - Database
    - 5 minute frequency unit gate setting and discharge
    - Turbines 1-14
    - Spill bays 1-22
    - Forebay and Tailwater elevation


McNary Dam
Temperature (°C)
Flow (kcfs)
45
40
35
30
25
20
15
10
5
400
350
300
250
200
150
100
50
0
6/1
6/11
6/21
7/1
7/11
7/21
7/31
8/10
8/20
8/30
9/9
9/19
9/29
MCQO-OBS
FB CAL
MCPW-OBS
SP CAL
REL CAL
J DA-OBS
J DA-CAL
MCQW-OBS
Qriver
Qspill
Wind

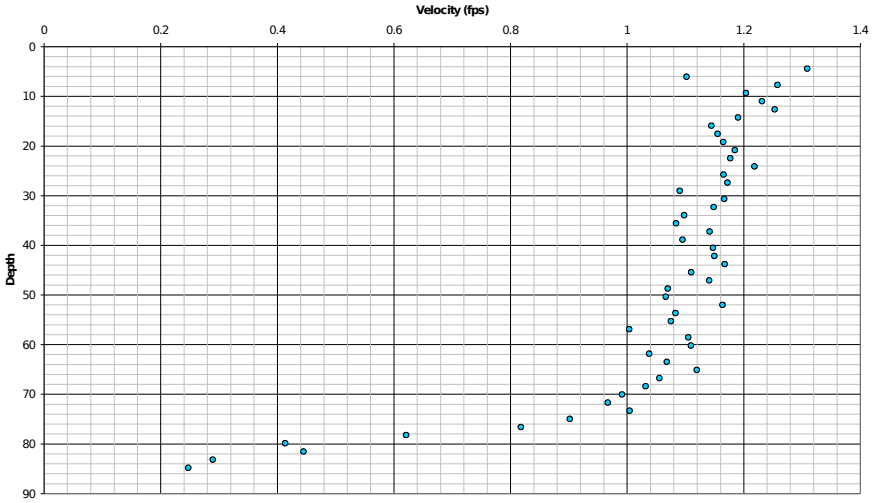

McNary Dam
Temperature (°C)
Flow (kcfs)
45
40
35
30
25
20
15
10
5
400
350
300
250
200
150
100
50
0
6/1
6/11
6/21
7/1
7/11
7/21
7/31
8/10
8/20
8/30
9/9
9/19
9/29
MCQO-OBS
FB CAL
MCPW-OBS
SP CAL
REL CAL
J DA-OBS
J DA-CAL
MCQW-OBS
Qriver
Qspill
Wind

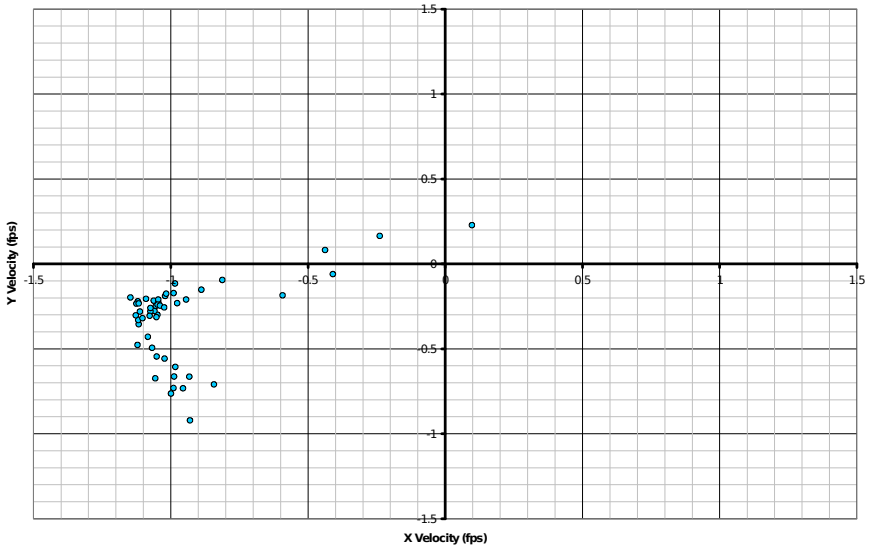

Forebay Elevation (ft)
340
339
338
337
336
335
1/14/2004 0:00
3/4/2004 0:00
4/23/2004 0:00
6/12/2004 0:00
8/1/2004 0:00
9/20/2004 0:00
11/9/2004 0:00

McNary Dam & Forebay Thermal Characterization
2004

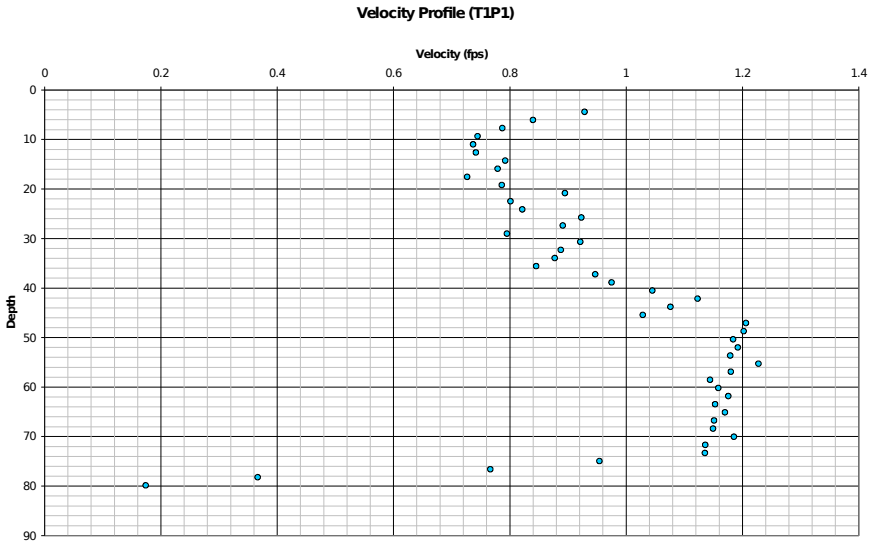
- Velocity field
  - ADCP Sampling
    - July 20-21 Mobile Transecting
      - Transects T4, T5, T6, T8
      - July 20 142-162 kcfs/ windy
      - July 21 136-164 kcfs / Calm winds
    - August 16-17 Stationary Samples
      - Transects T1, T3, T6
      - August 16 148-171 kcfs
      - August 17 125-138 kcfs
  - Database 800,000 records

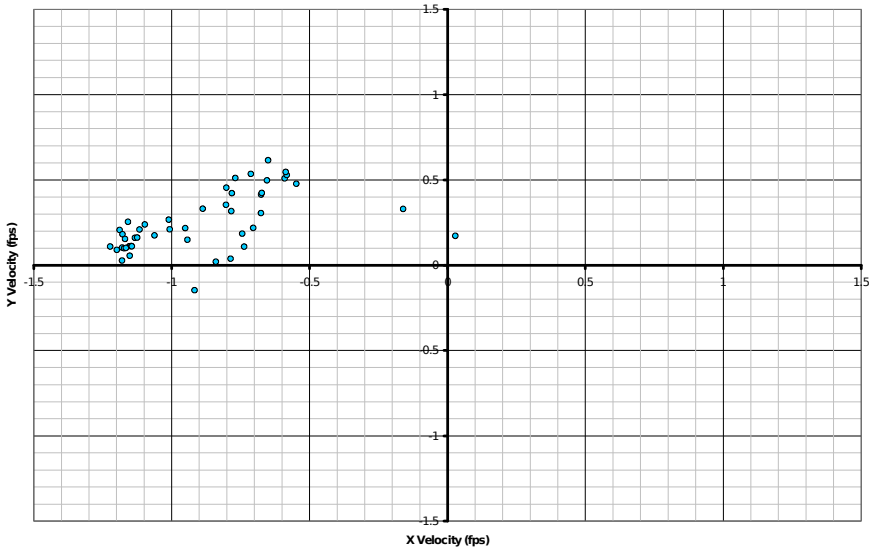
Velocity Profile and Direction at Station T1P6

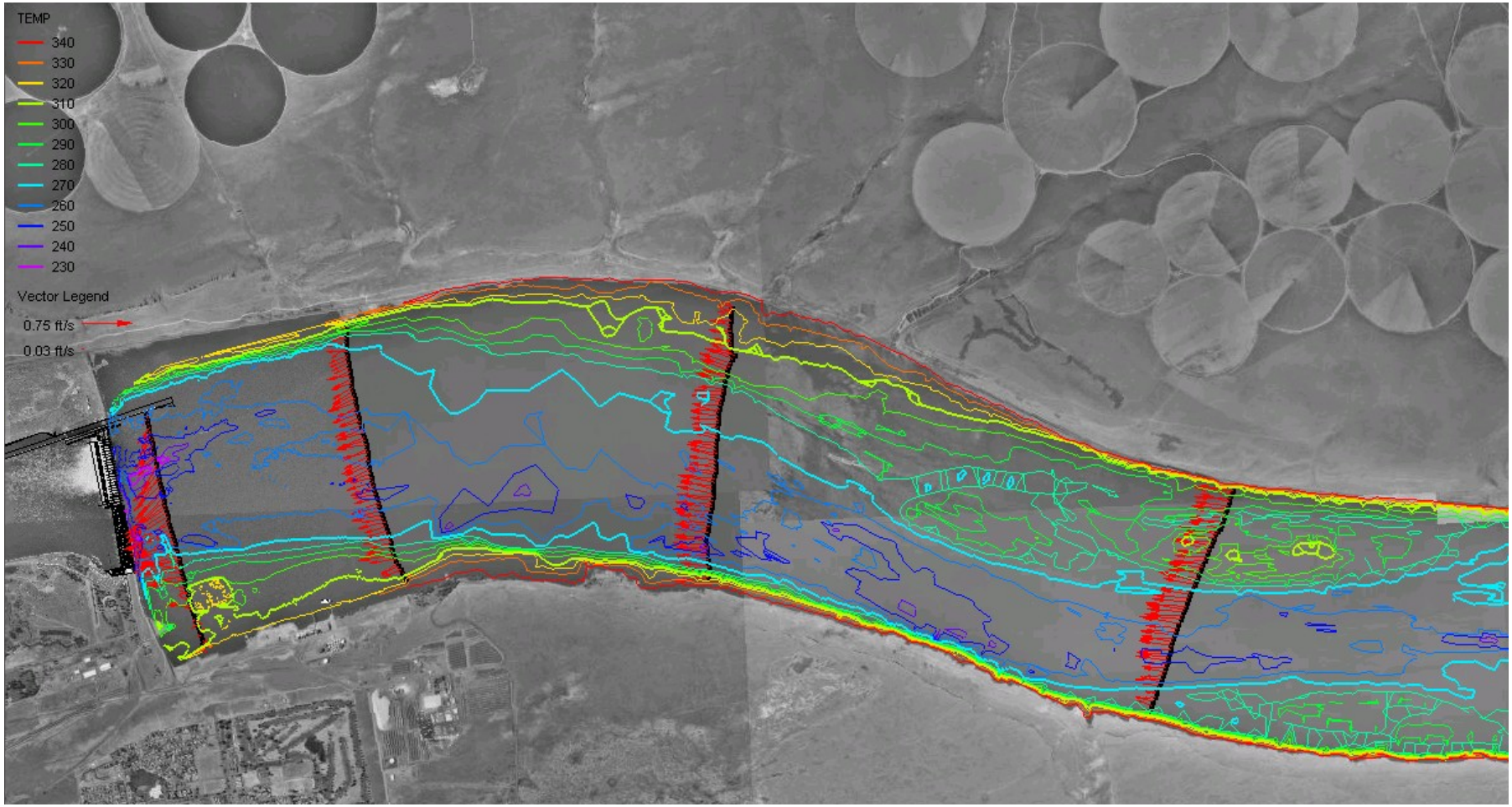




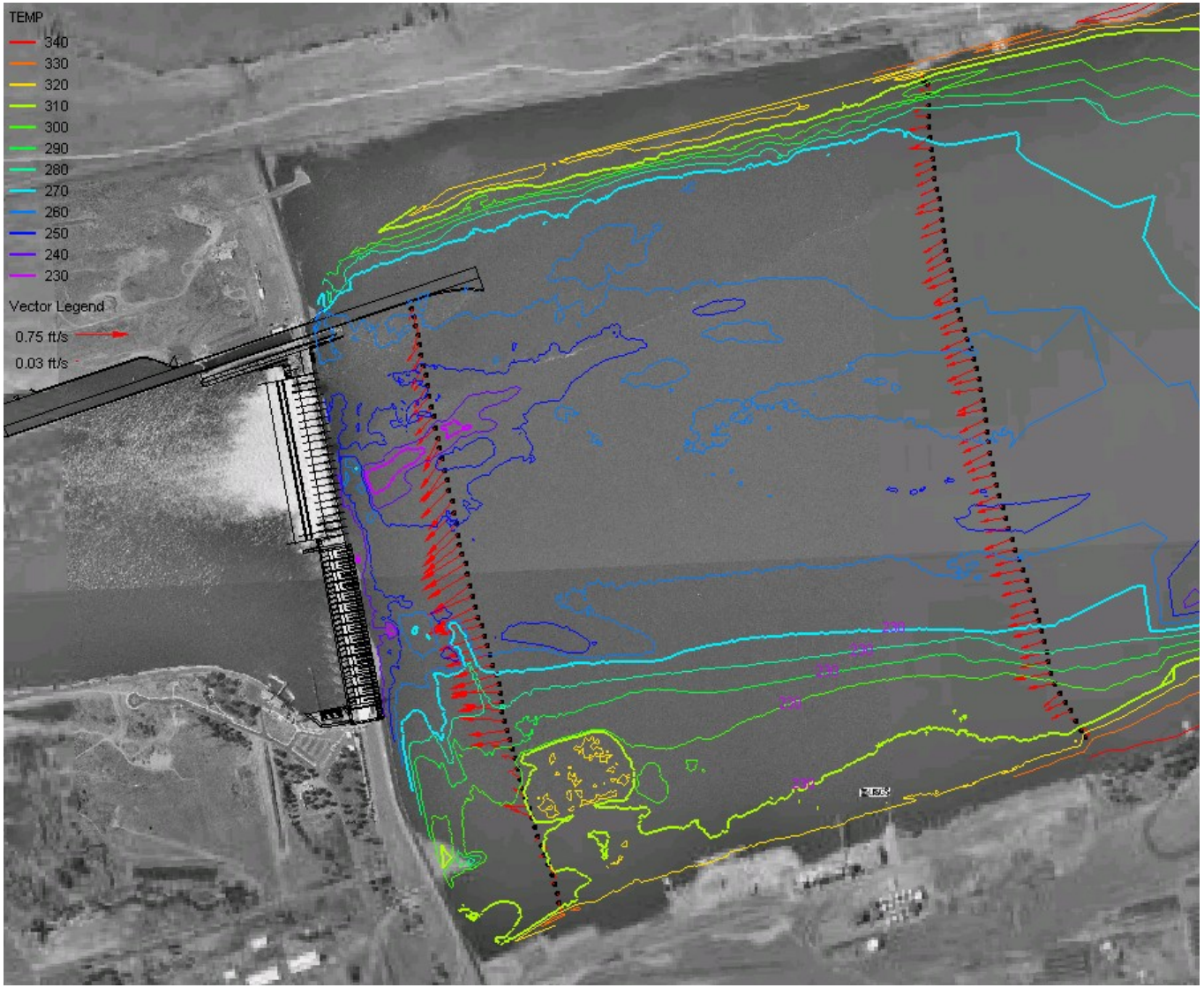
Velocity Profile and Direction at Station T1P1



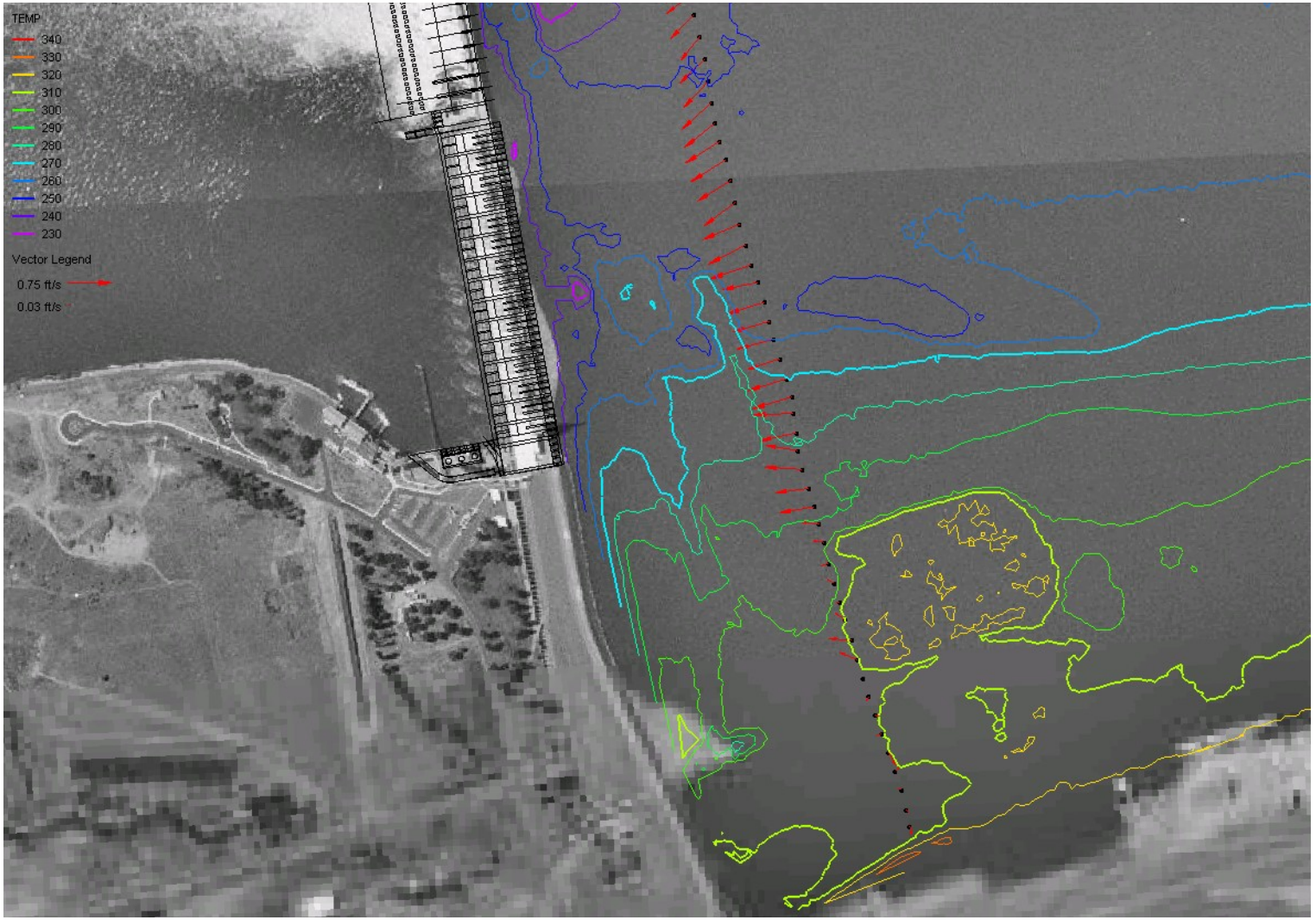




Depth Averaged Velocities in the Columbia River upstream of McNary Dam



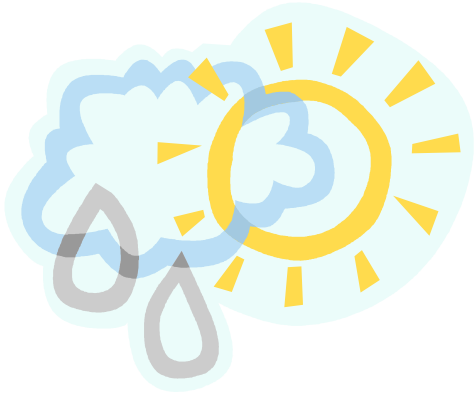
Depth Averaged Velocities in the Columbia River upstream of McNary Dam



Depth Averaged Velocities in the Columbia River upstream of McNary Dam

McNary Dam & Forebay Thermal Characterization
2004

- Meterologic Data
  - Location
  - Parameters
    - Air Temperature
    - Wind Speed and Direction
    - Short Wave Radiation
    - Long Wave Radiation
    - Relative Humidity



2004 Meteorological Data Review

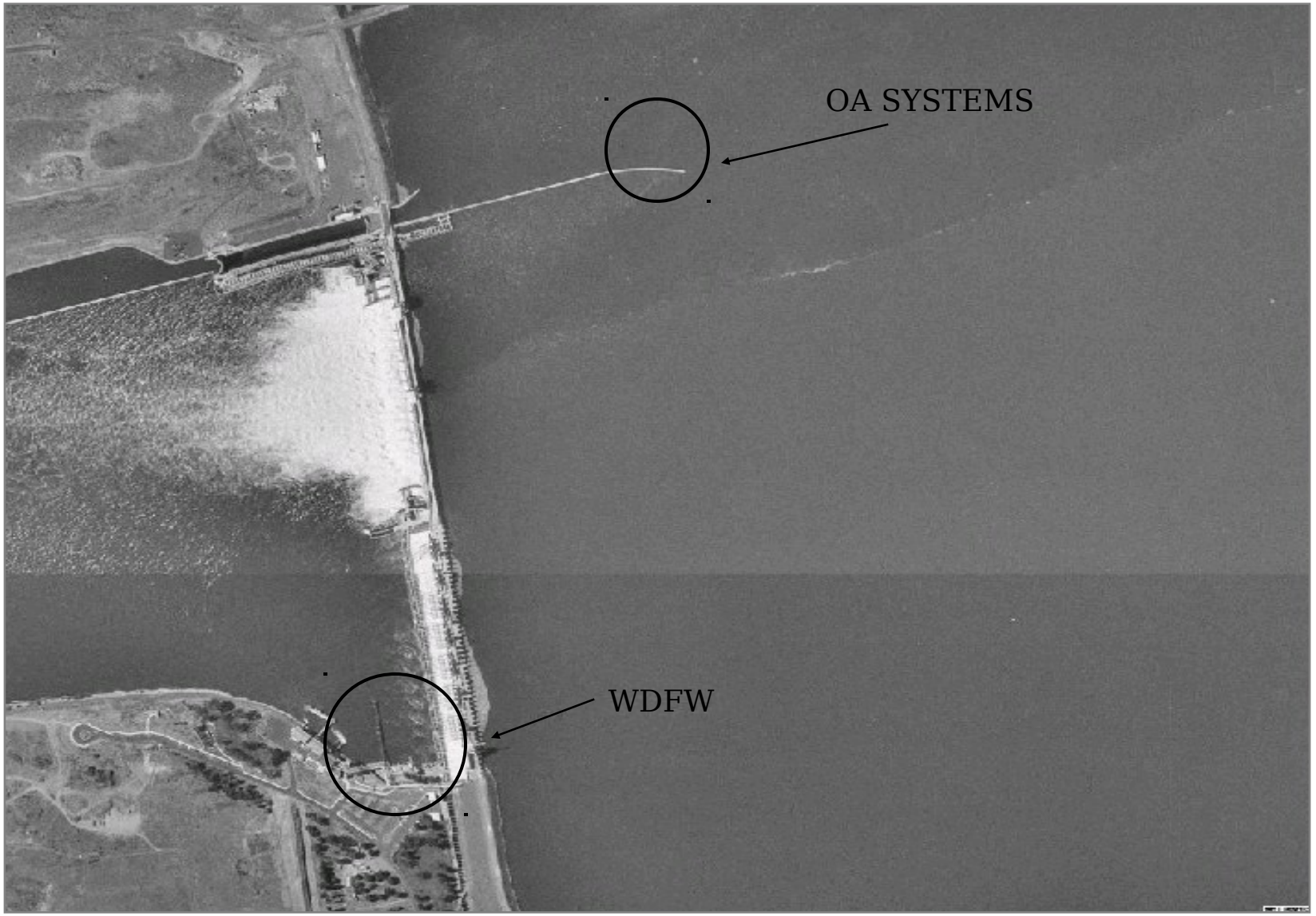
Weather Data Collected Near McNary Dam, 2004

- Bureau of Reclamation Hermiston, OR AgriMet Weather Station
  - Data collected for the entire 2004 year
  - Collection frequency of 15 minutes

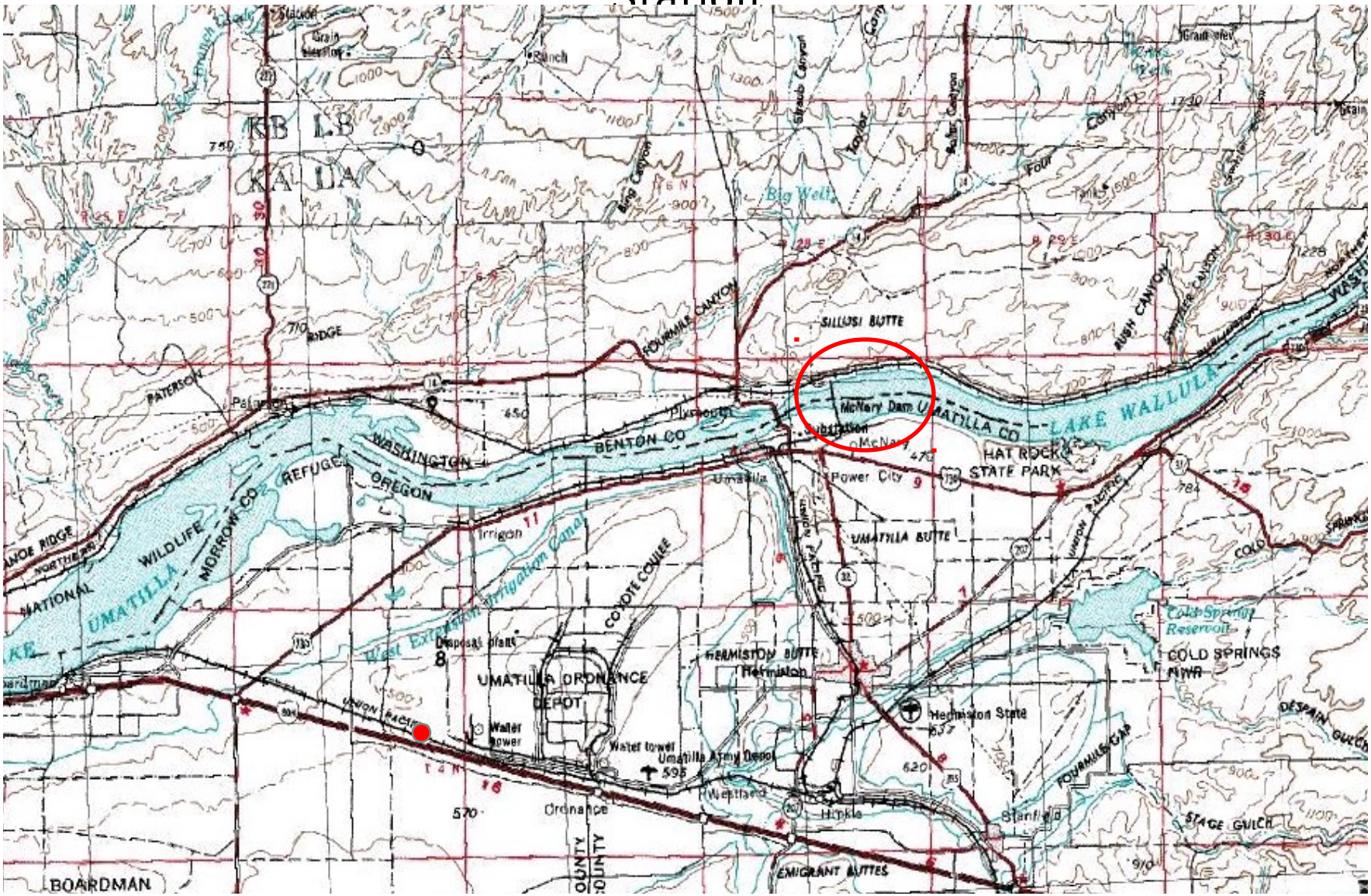
- Washington Fish and Wildlife Service Weather Station
  - Data collected from July 7 - August 31, 1004
  - Collection frequency of 30 minutes

- Walla Walla District/OA Systems Weather Station
  - Data collected from July 16 - August 3, 2004, August 18 – August 31, 2004
  - Collection frequency of 10 minutes

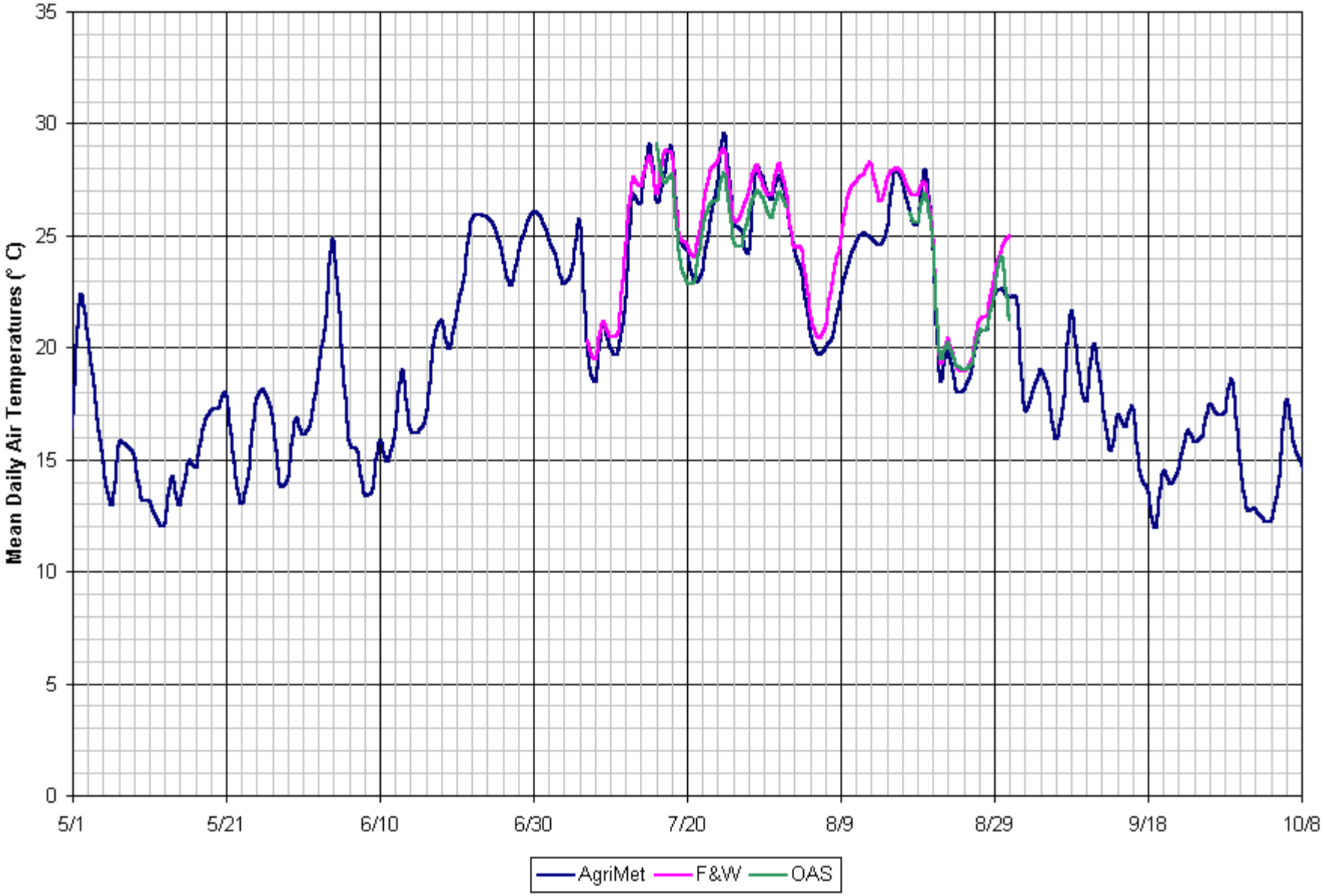
Aerial Photo of the WA Fish and Wildlife and OAS Weather Stations



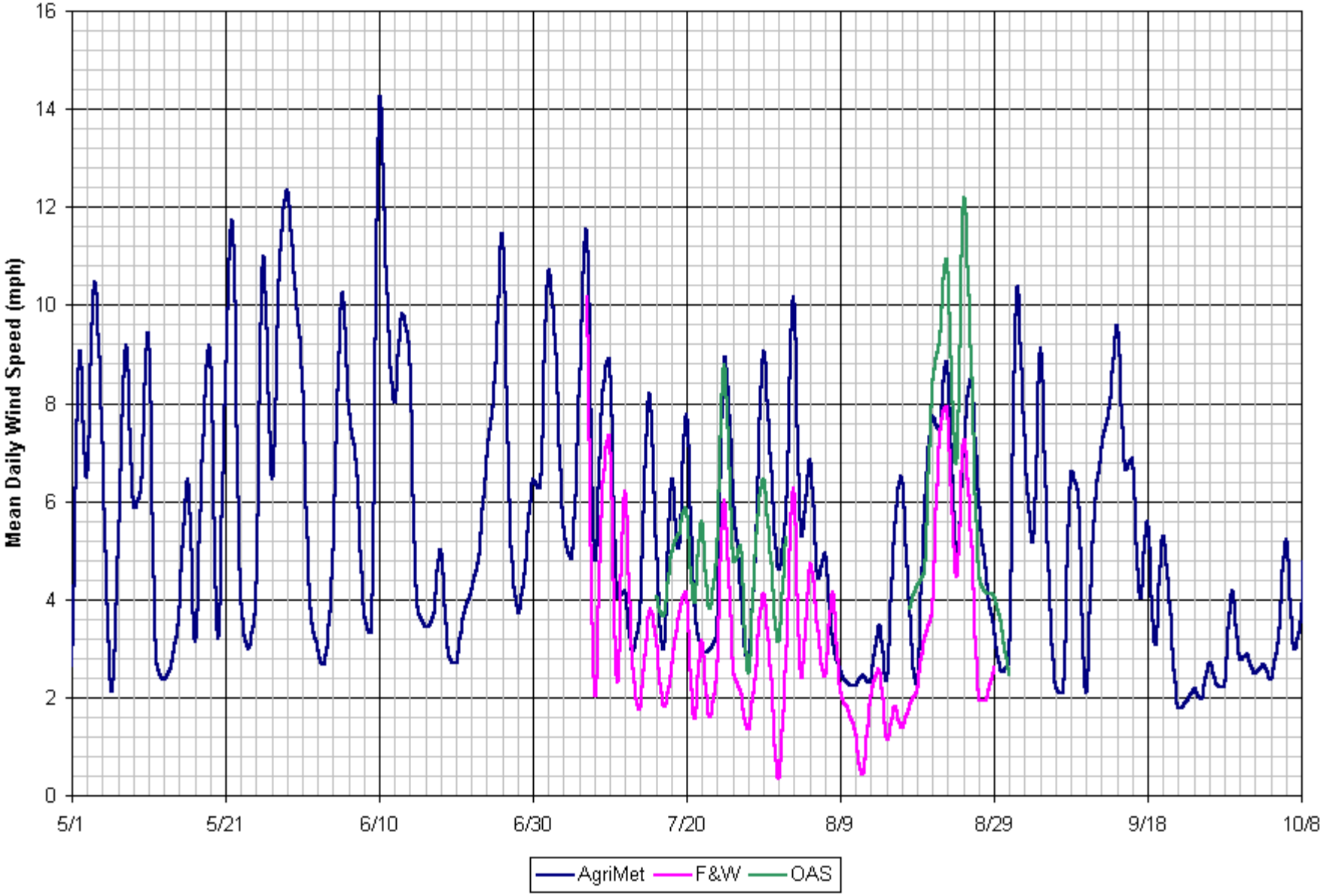
Topographic Map of AgriMet, Hermiston, OR Weather Station

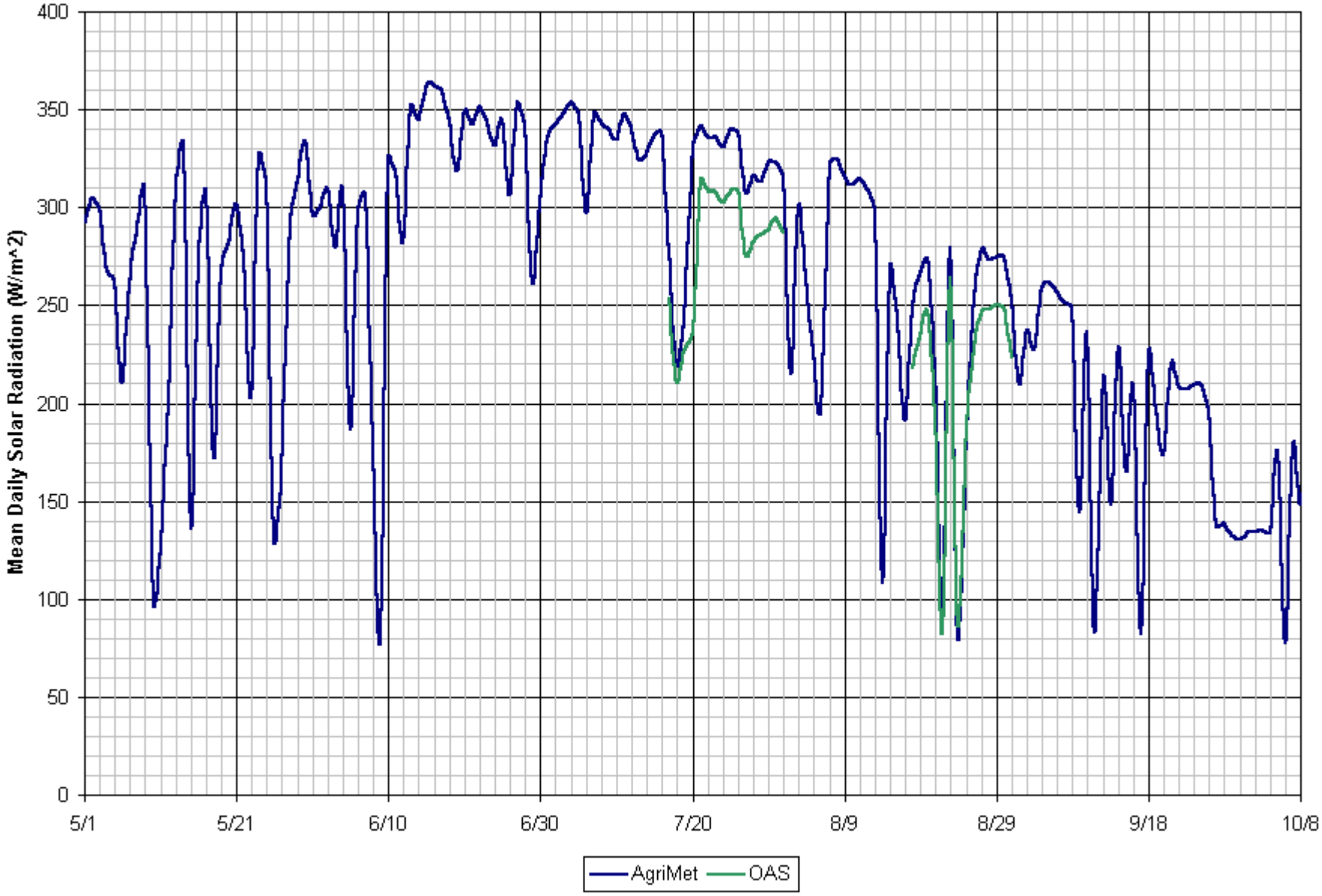

McNary Dam
UMATILLA CO
LAKE WALLULA
BENTON CO
WASHINGTON
OREGON
REFUGE
UMATILLA
WILDLIFE
MORROW CO
HAT ROCK
STATE PARK
Power City
Umatilla
Irrigon
West Extension Irrigation Canal
UMATILLA BUTTE
SILLUSI BUTTE
HERMISTON BUTTE
Hermiston
UMATILLA ORDNANCE
DEPOT
Ordnance
Hermiston State
COLD SPRINGS
RESERVOIR
Cold Spring
Reservoir
Hinkle
Stanfield
EMIGRANT BUTTES
BOARDMAN
Big Wells
Paterson
Plymouth
Irrigation
McNary
Water tower
Water tower
Umatilla Army Depot
Wetland
Disposal plant
Water tower
Grain elev
Ranch
Station
Grain elev
Tanks
Tanks
Big Canyon
Strawb Canyon
Taylor
Four
Fourmile Canyon
Bush Canyon
Coyote Coulee
Stage Gulch
Despain Gulch
Fourmile Gap
Union Pacific
Union Pacific
Union Pacific
Northern
Northern
Cold
Spring
Irrigation
Canal
Ridge
Bridge
Creek
Branch
Lake
Lake
Lake

Mean Daily Air Temperatures Measured During the 2004 Year

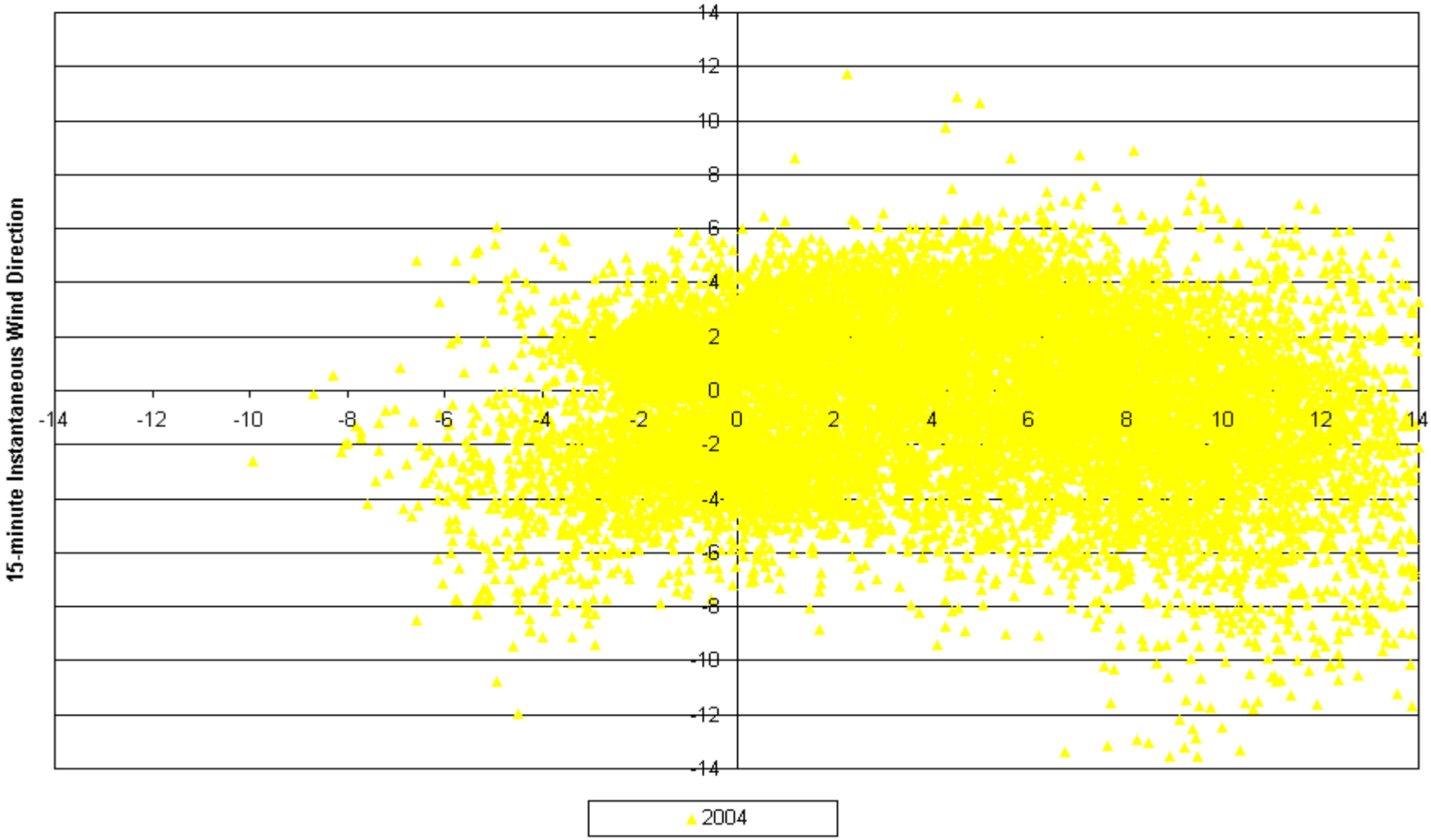


Mean Daily Wind Speed (mph) Measured During the 2004 year

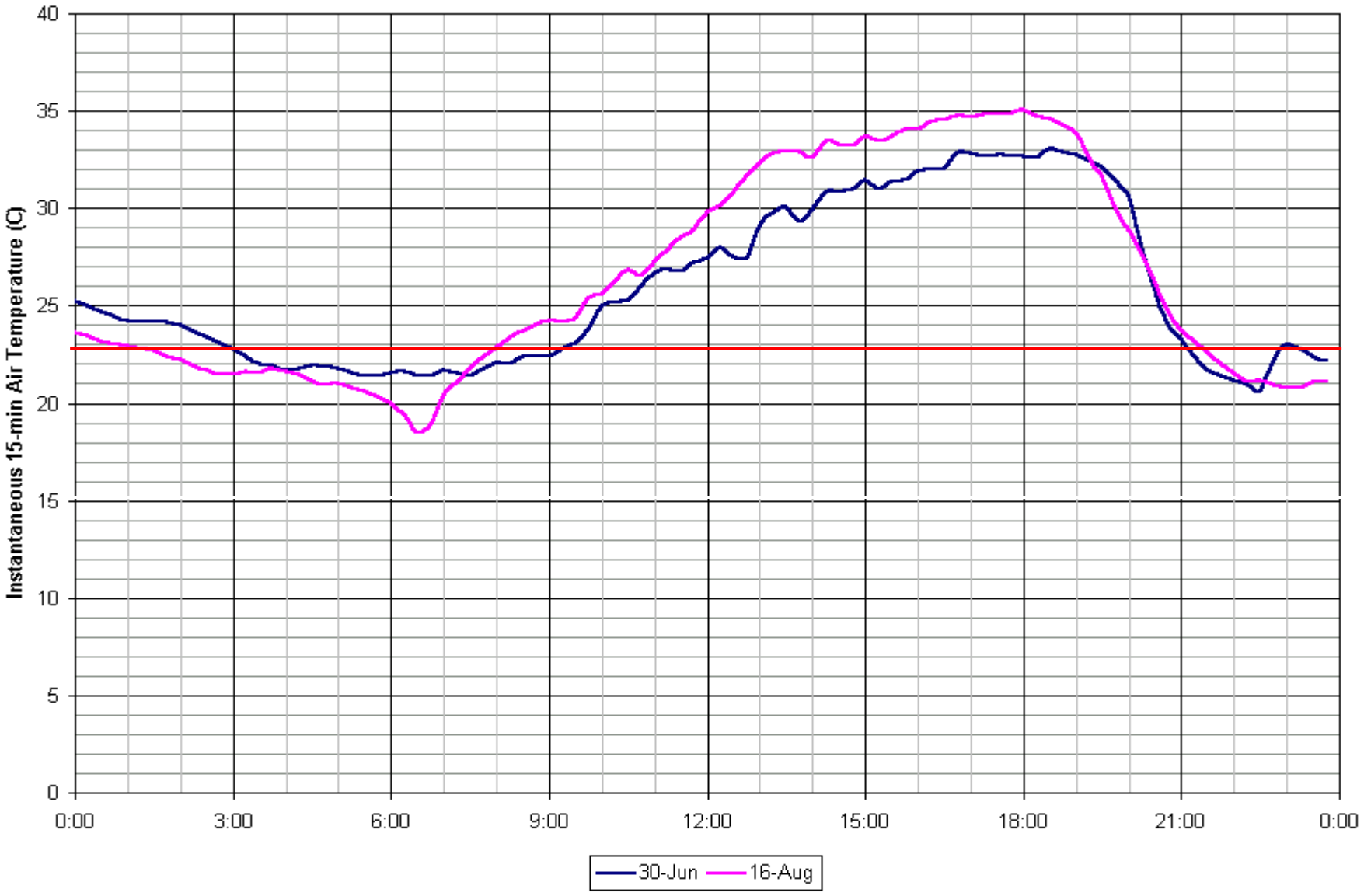



Mean Daily Solar Radiation (W/m^2)
400
350
300
250
200
150
100
50
0
5/1
5/21
6/10
6/30
7/20
8/9
8/29
9/18
10/8
AgriMet
OAS

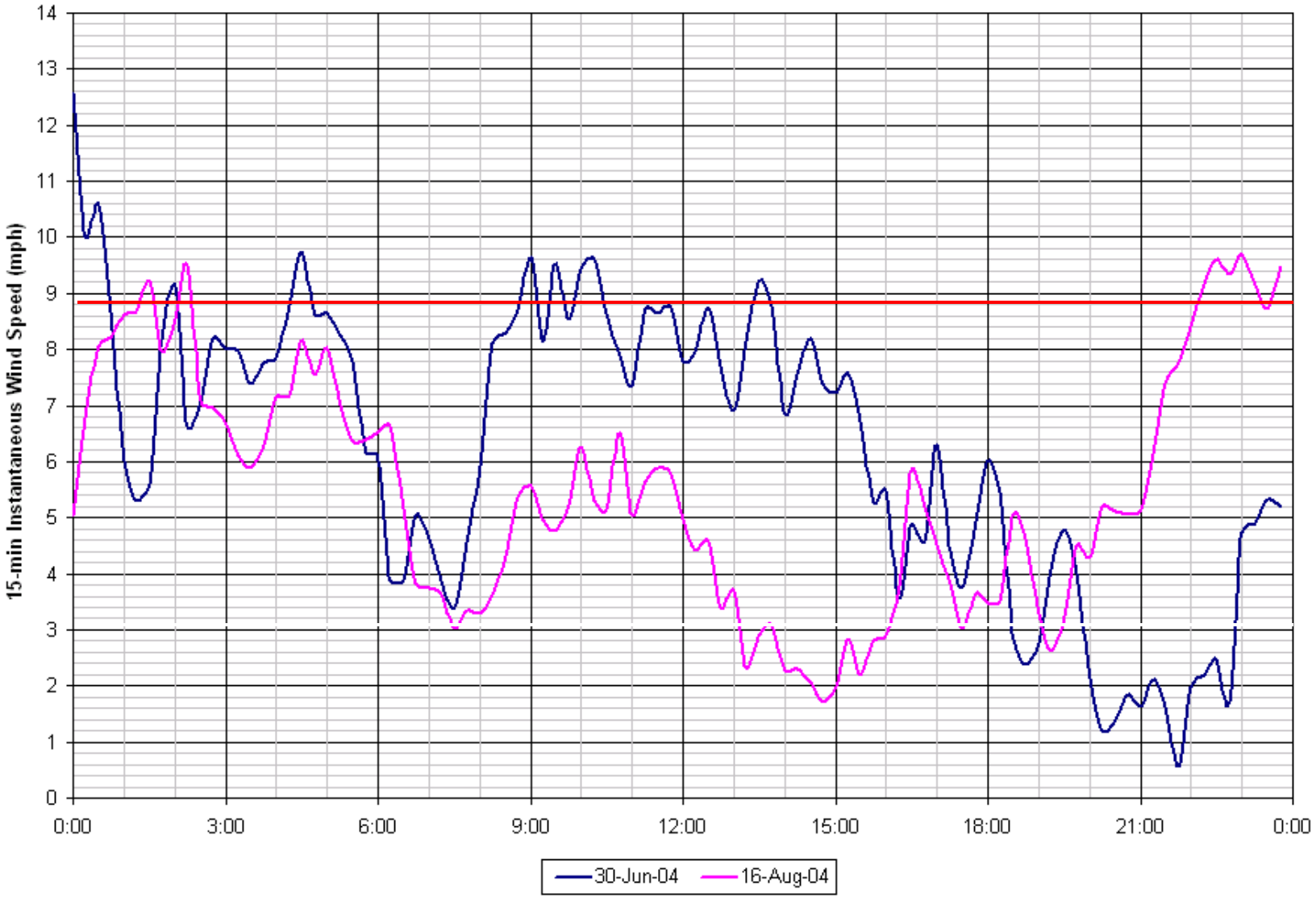
Instantaneous Wind Direction Measured at the Hermiston, Oregon AgriMet Weather Station, May-September, 2004



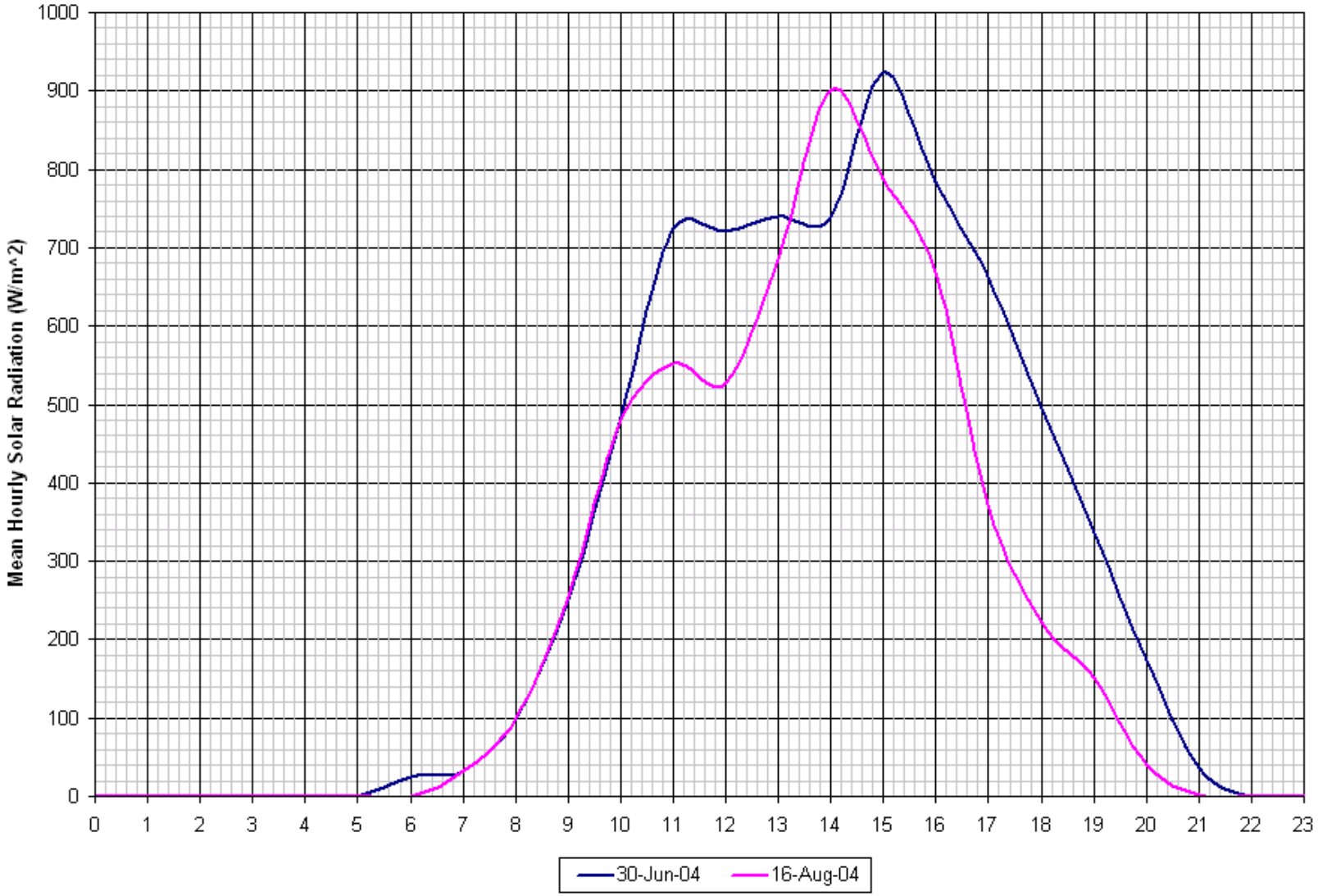
Instantaneous Air Temperature measured at the Hermiston, Oregon AgriMet Weather Station, June 30



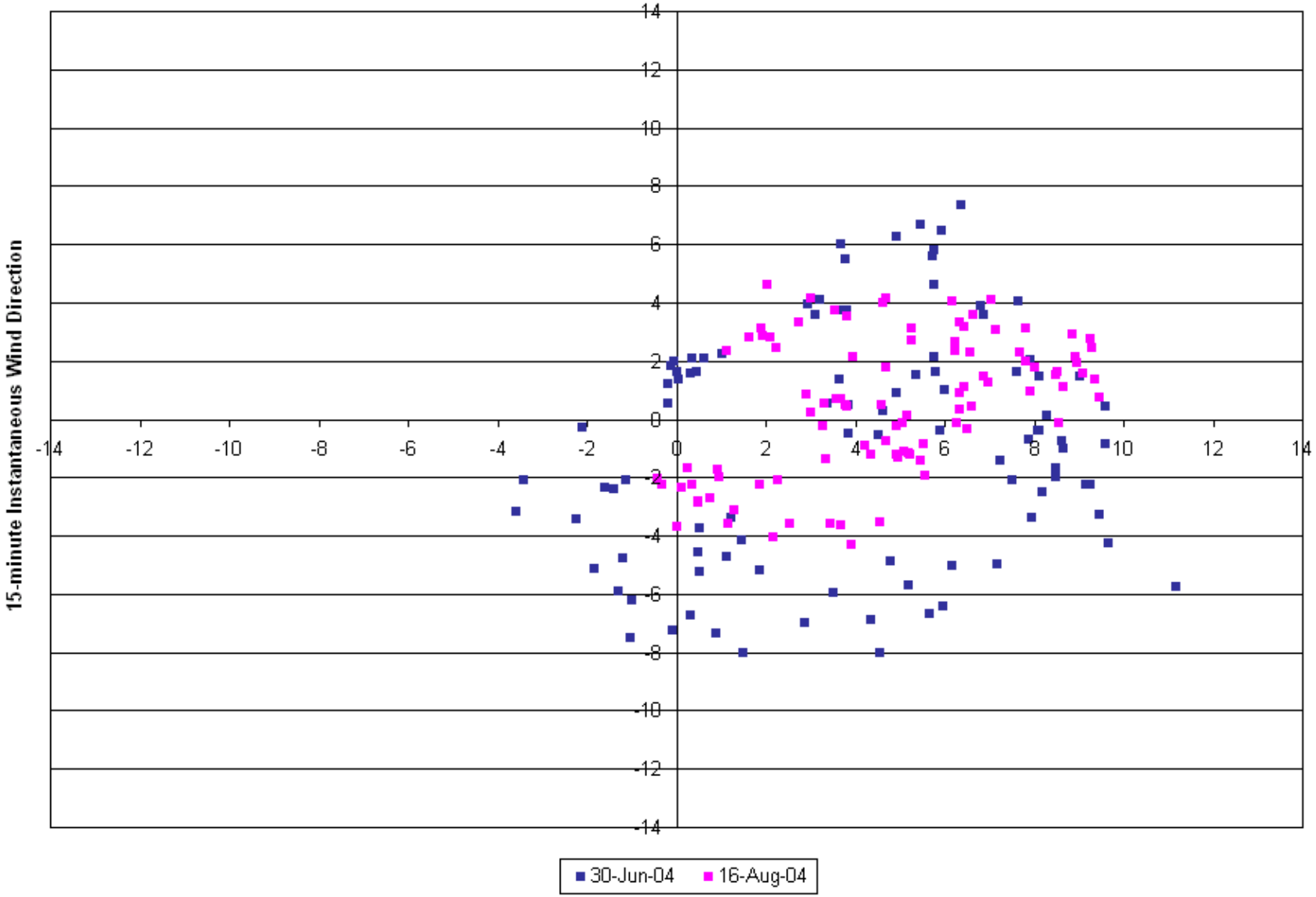
Instantaneous Wind Speed (mph) measured at the Hermiston, Oregon AgriMet Weather Station, June 30, 2004 and August 16, 2004



Instantaneous Hourly Solar Radiation Measured at the Hermiston, Oregon AgriMet Weather Station, June 30, 2004 and August 16, 2004



Instantaneous Wind Direction Measured at the Hermiston, Oregon AgriMet Weather Station, June 30, 2004 and August 16, 2004



Conclusions-Air Temperature

- Air temperature is variable among the weather stations.

  - Weather station over water had a narrower range of responses than weather stations over land

- Air and water temperatures respond to similar meteorologic inputs

- Air temperatures generally peak in late afternoon during the summer months, approximately 2 to 3 hours after solar radiation peaks.

- Air temperature is a key parameter in estimating heat flux into the water column

Conclusions - Wind

- Wind is highly variable temporally and spatially among the three stations.

- Wind is a good predictor of how well surface waters mix.

  - strong temperature gradients in forebay can develop during calm to moderate winds

  - high wind creates waves which provide turbulence and mixing at the water surface

- Wind can influence the forebay circulation patterns.

  - a strong wind will pile up warm water in the down wind direction and up well cool water in the upwind direction.

- Evaporative heat loss if related to wind.

Conclusions – Solar Radiation

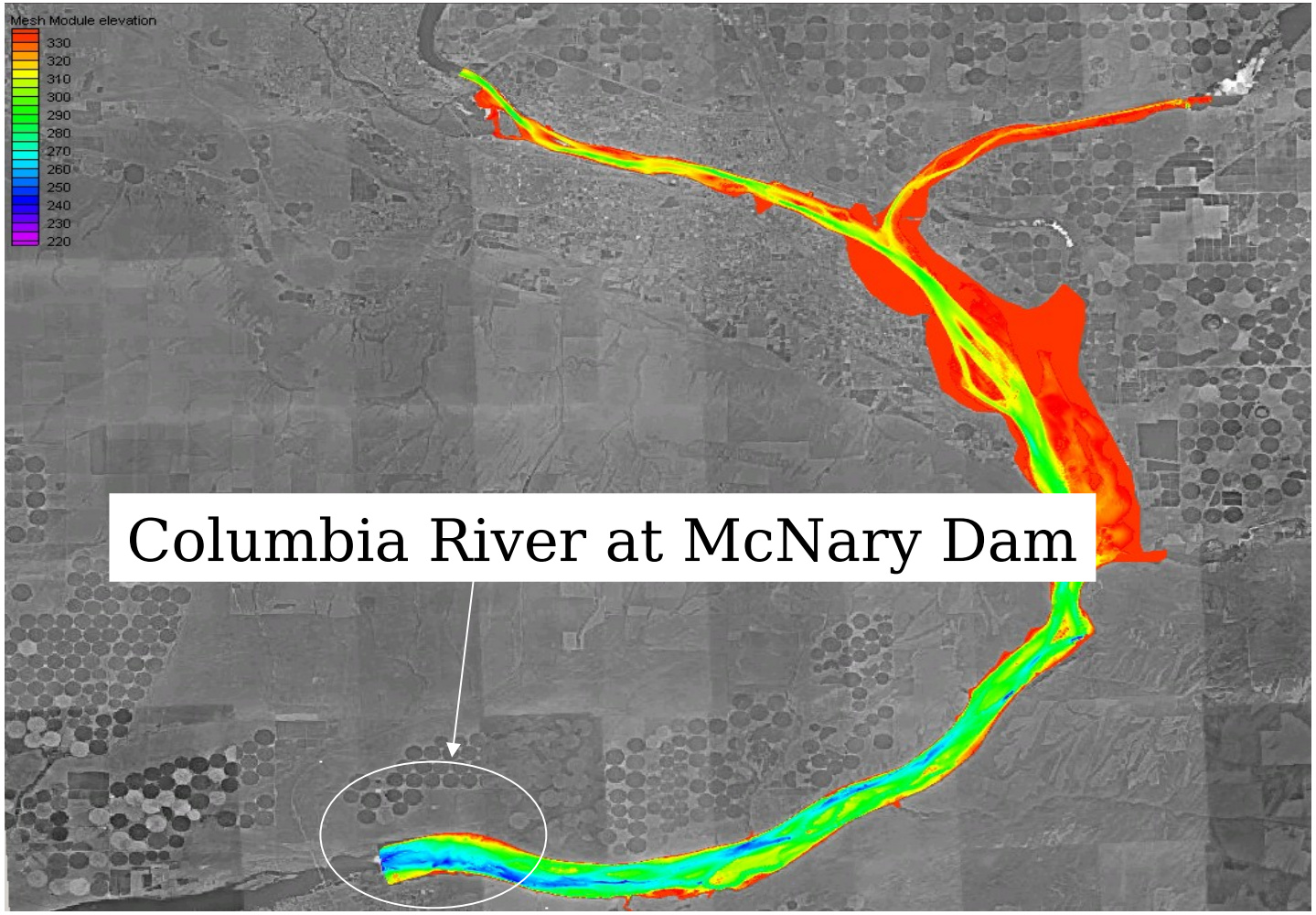
- Solar radiation is the primary source of heat flux into the water column.

- The absorption of short wave solar radiation in the water column is approximated as an exponential decay with depth
  - Function of water clarity
- Net long wave radiation to the water column was negative
  - Exchange of long wave radiation is at the water surface

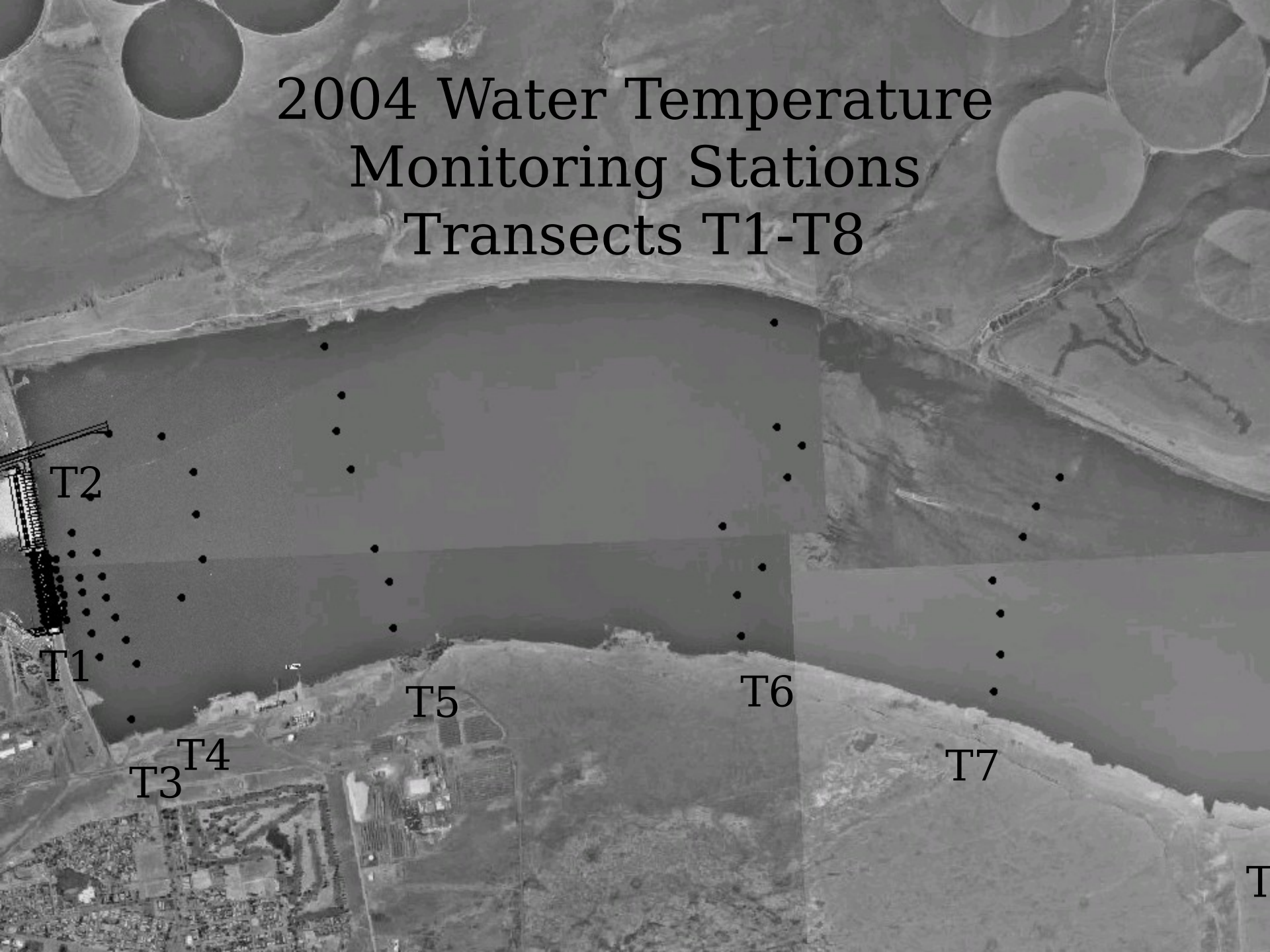
- Solar radiation flux varies over the course of the daylight hours and is impacted by cloud cover.

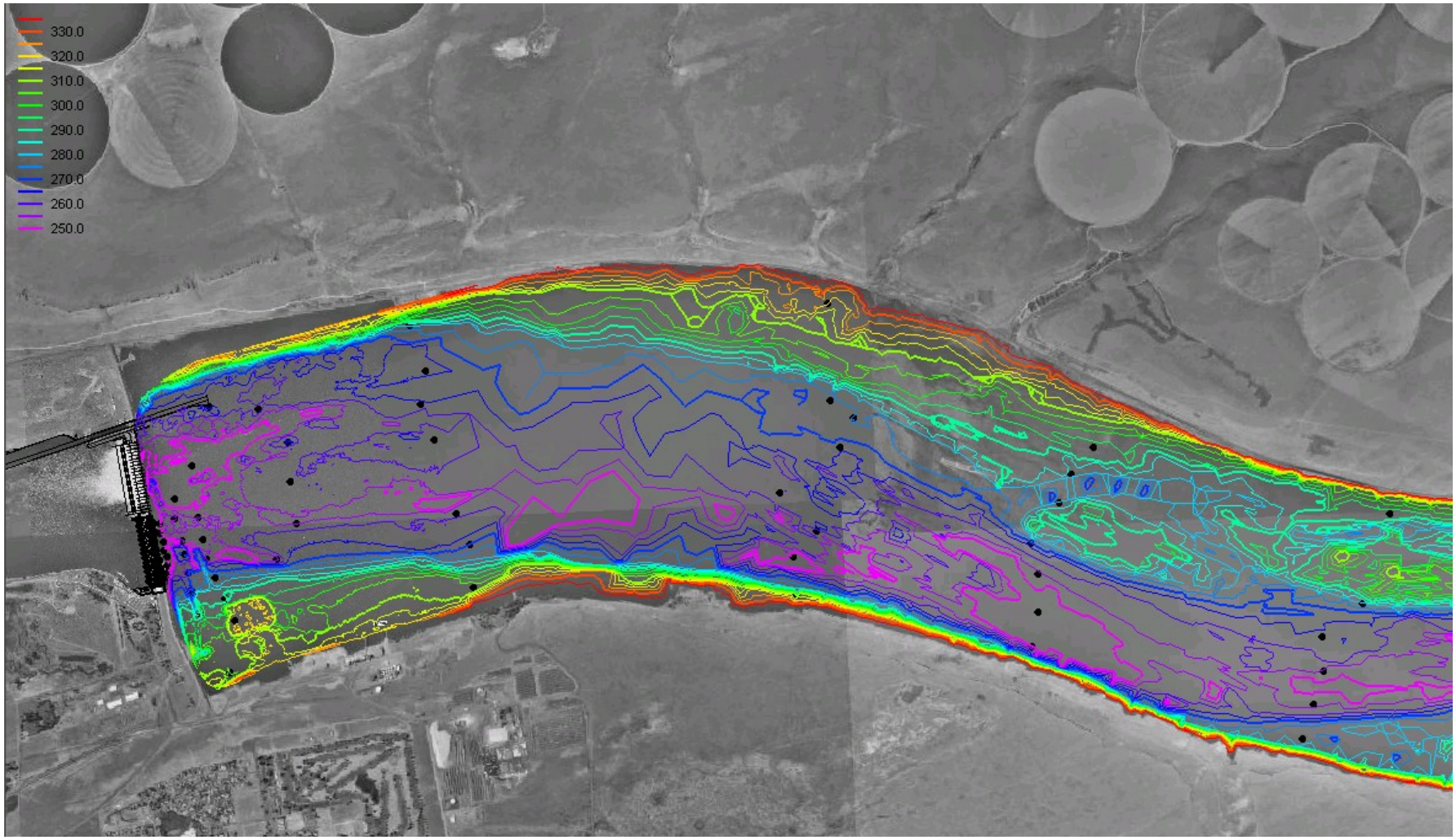
McNary Dam & Forebay Thermal Characterization
2004

- Temperature Data
  - Research Sampling Array (15 minute frequency)
    - Forebay Transects 1-8
      - Variable elevation
      - Depths (0.5, 1.5, 3, 5, 10, 15, 20, 25, 30, 35 meters)
    - Trash racks
    - Gate wells
    - Orifice Discharge
    - Tailwater channel
  - Routine Temperature Sampling WDFW
  - CE Walla Walla District
    - Fish ladders and juvenile bypass system
    - Fixed Monitoring Stations – TDG, Temp

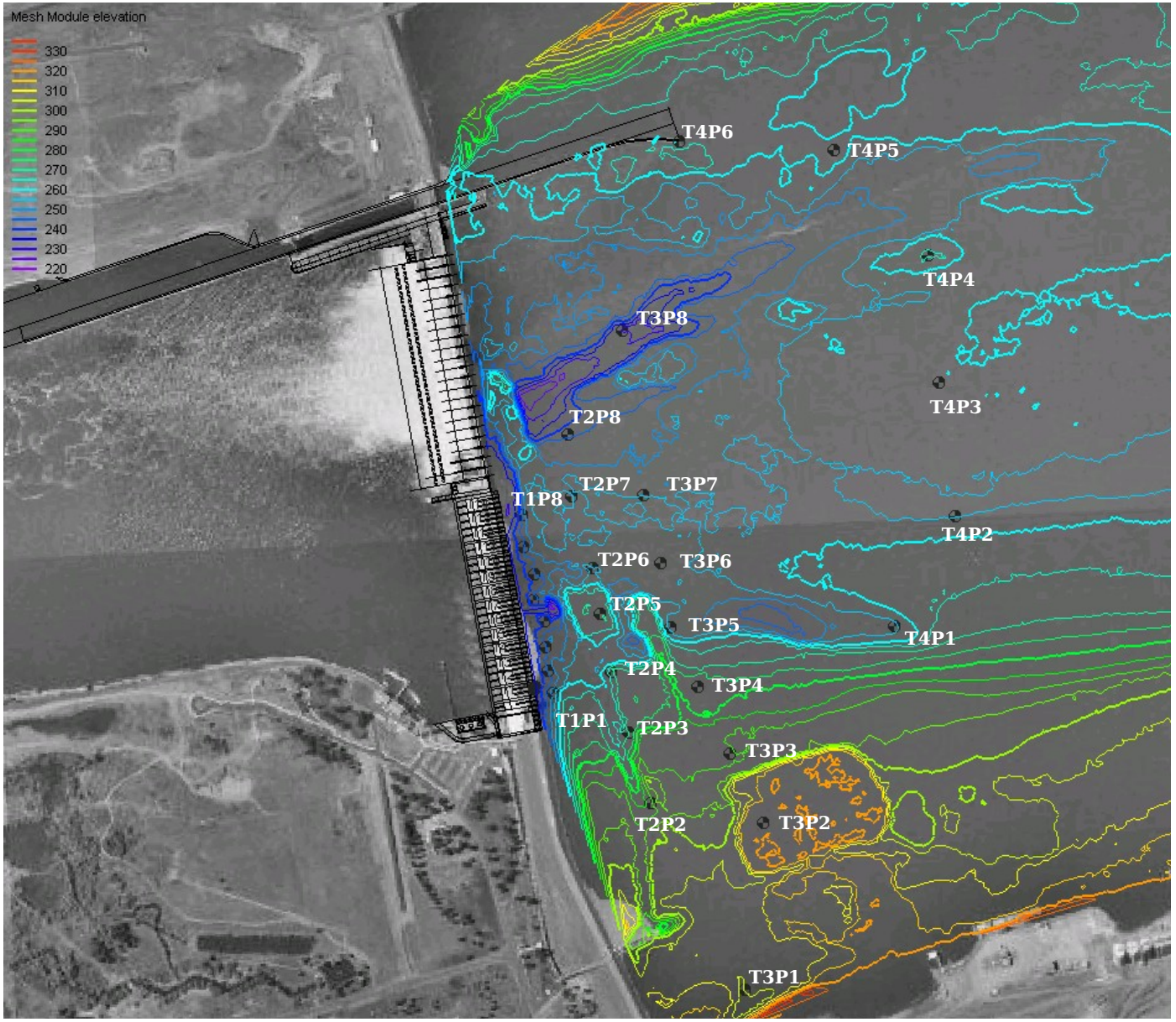


Columbia River Bathymetry Upstream of McNary Dam

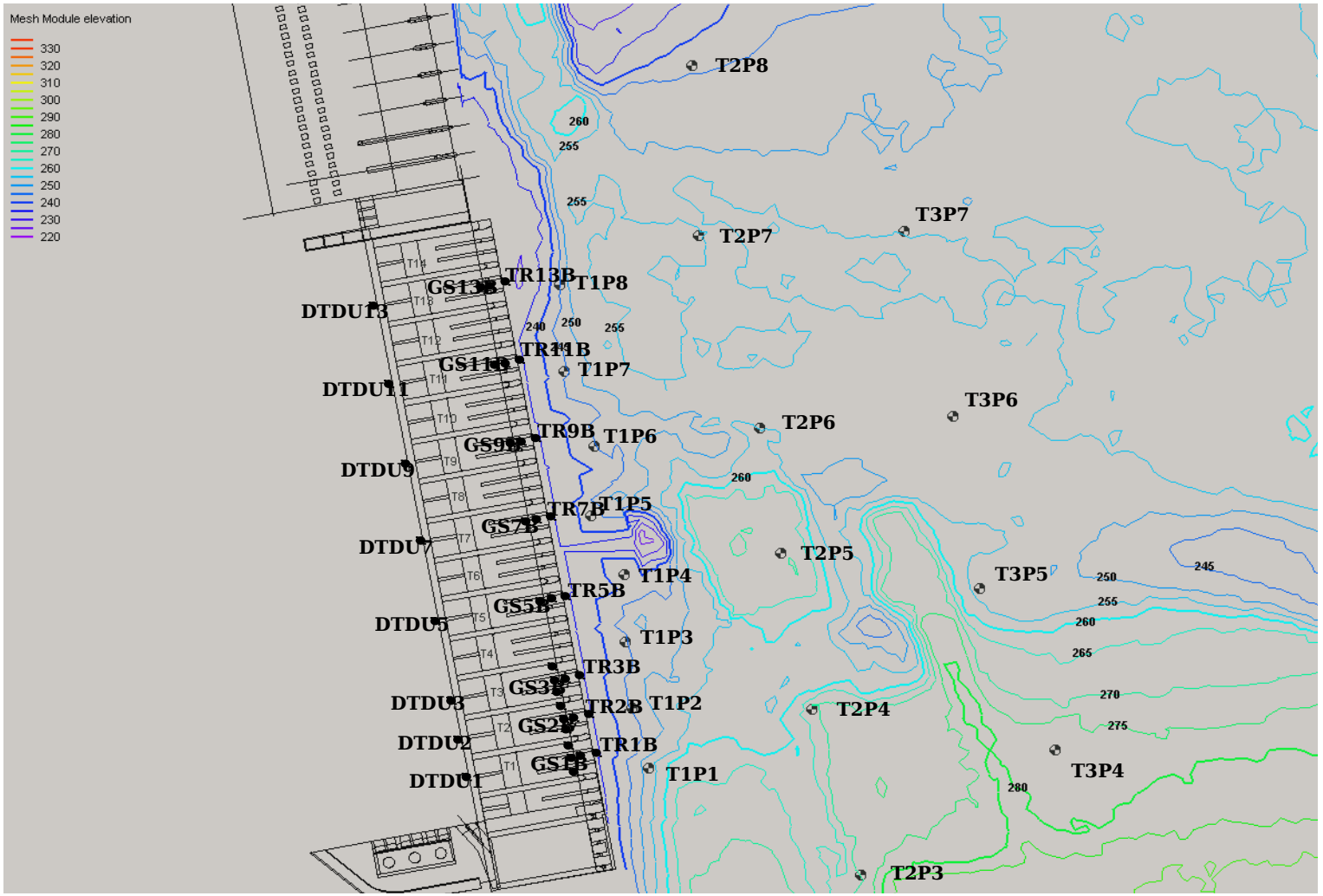

2004 Water Temperature
Monitoring Stations
Transects T1-T8
T2
T1
T5
T6
T4
T3
T7
T



Columbia River Channel Elevations and 2004 Water Temperature Monitoring Stations, transects T1-T8



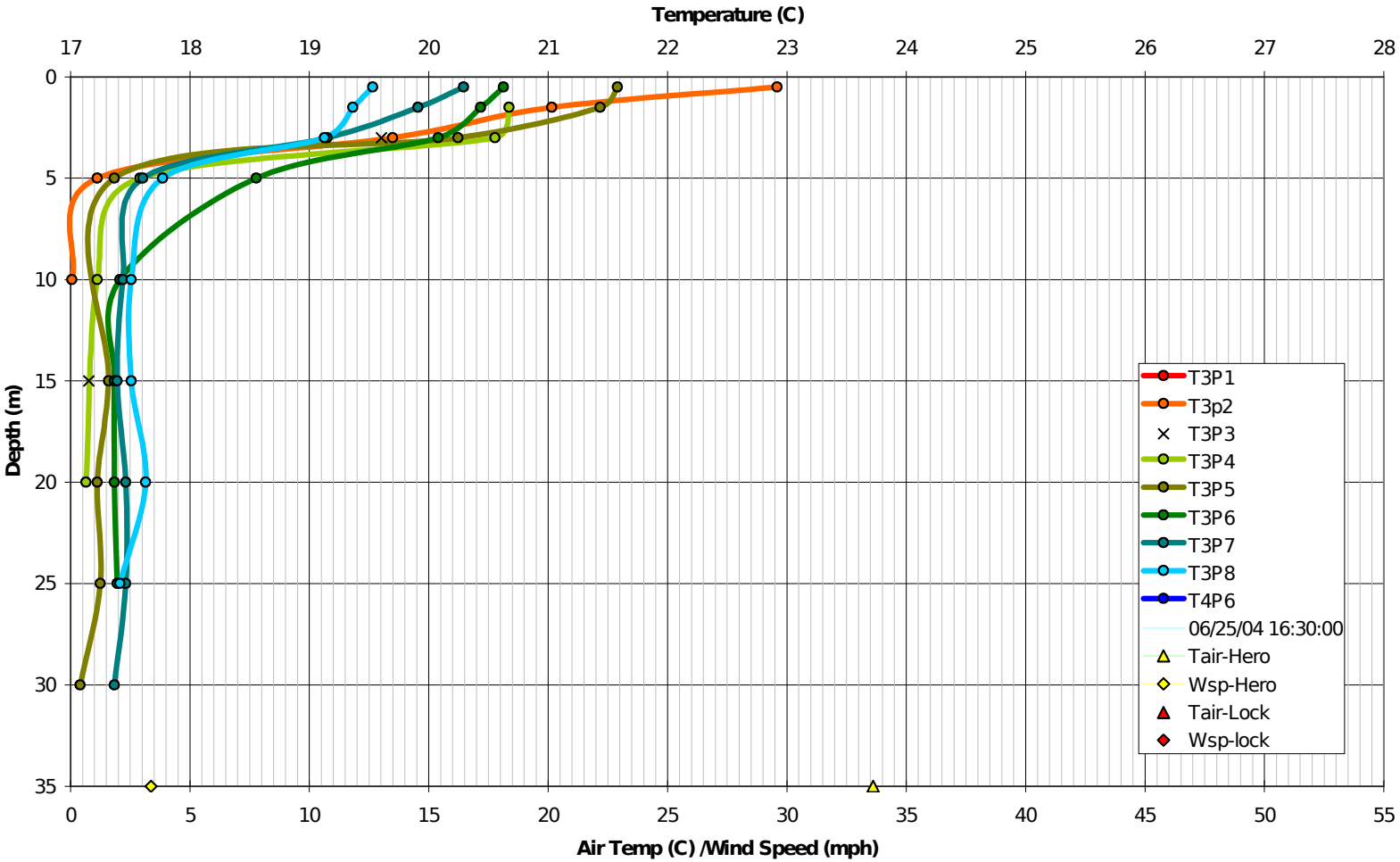
Columbia River channel elevations and 2004 water temperature monitoring stations, Transects T1-T4



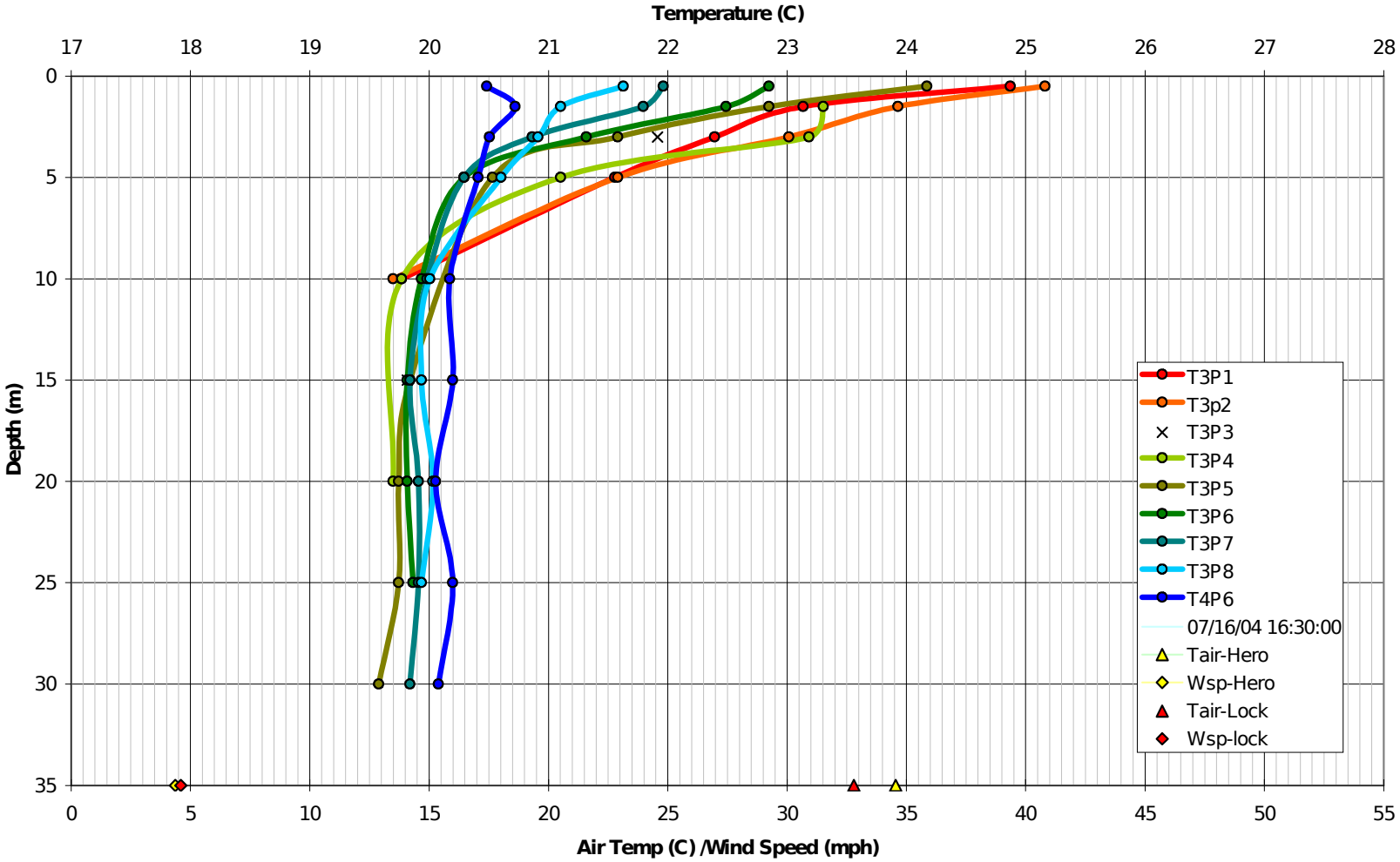
Columbia River channel elevations and 2004 water temperature monitoring stations, tailwater, gatewell, trashrack, and forebay transects t1-t3

McNary Dam & Forebay Thermal Characterization
2004

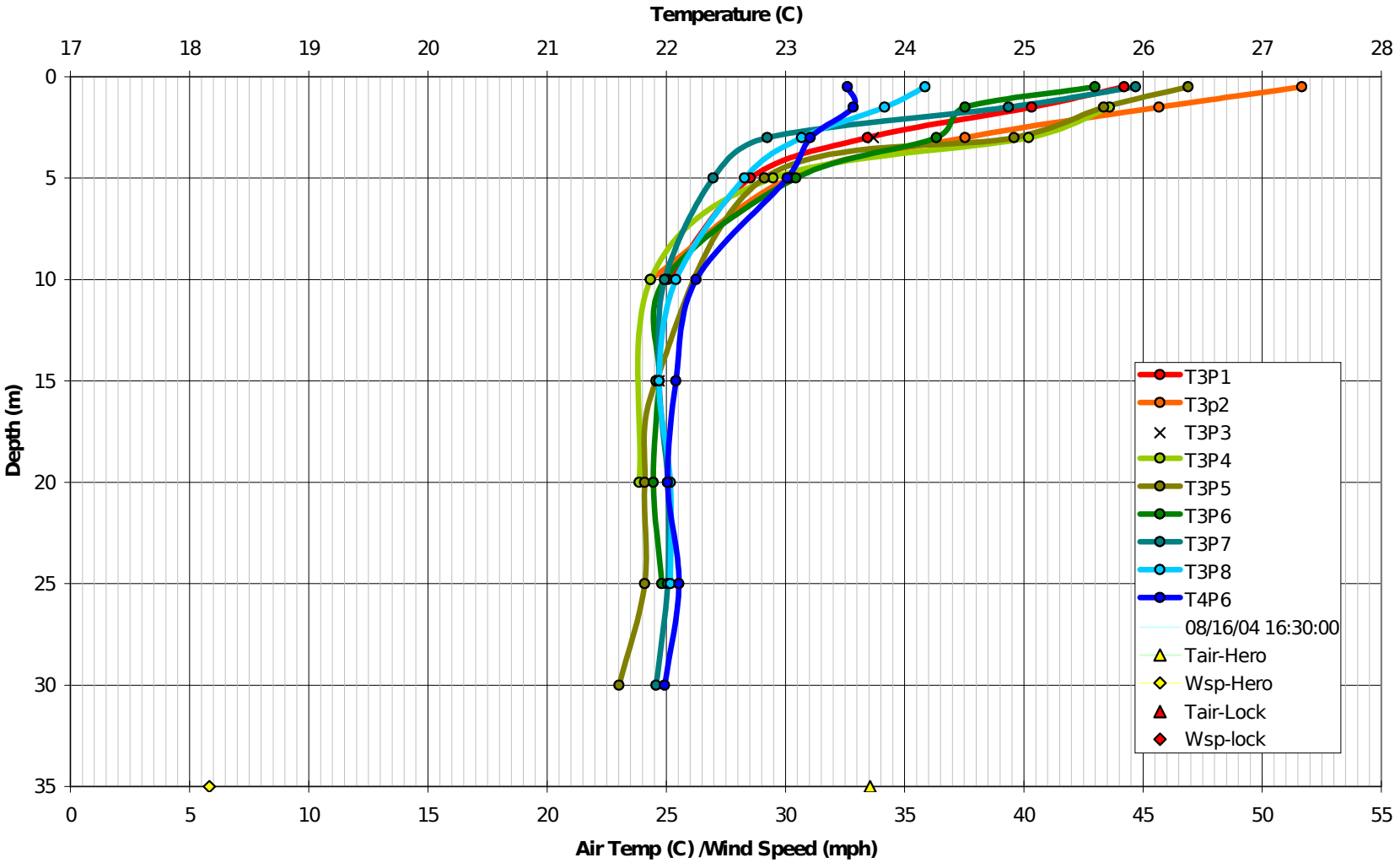
- Temperature Data Findings
  - Forebay
    - Periodic Stratification
      - » Development of warm surface layer
      - » Wind/Solar Input
    - Vertical temperature gradients 6 C
    - Surface Temperatures 28 C
    - Tendency for South Shore to warm up first
      - » Maximum surface temperature
      - » Propagation of warm temperature to dam
    - Transient Propagation of Thermal Fronts
    - No sign of systematic lateral subsurface temperature gradients
      - » No residual thermal signature from Snake River
    - Down welling of warm water at face of dam



Temperature profiles in McNary Forebay on Transect T3 and at the lock guide wall (T4P6)
June 25, 2004 at 16:30 hrs



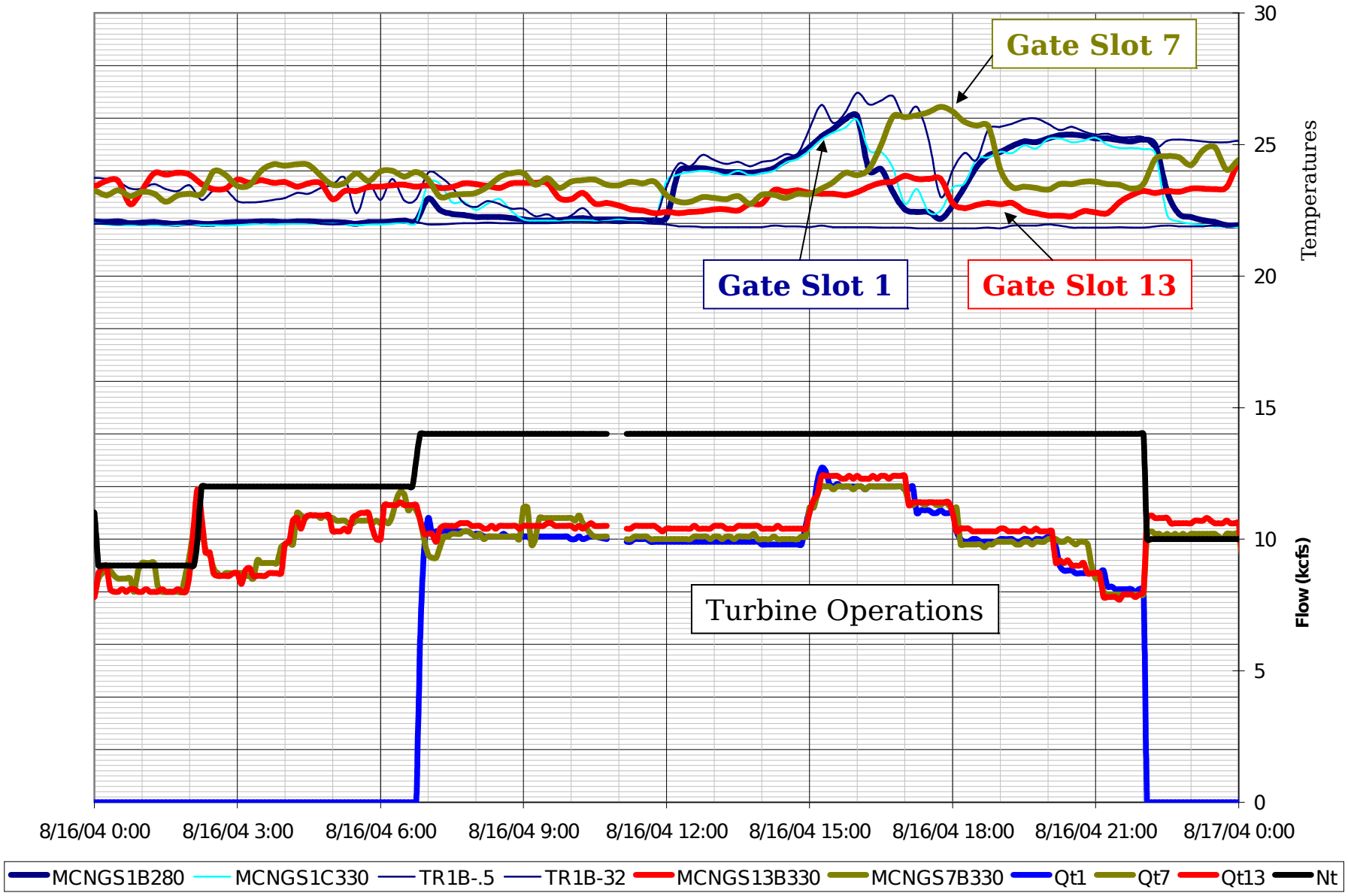
Temperature profiles in McNary Forebay on Transect T3 and at the lock guide wall (T4P6)
July 16, 2004 at 16:30 hrs



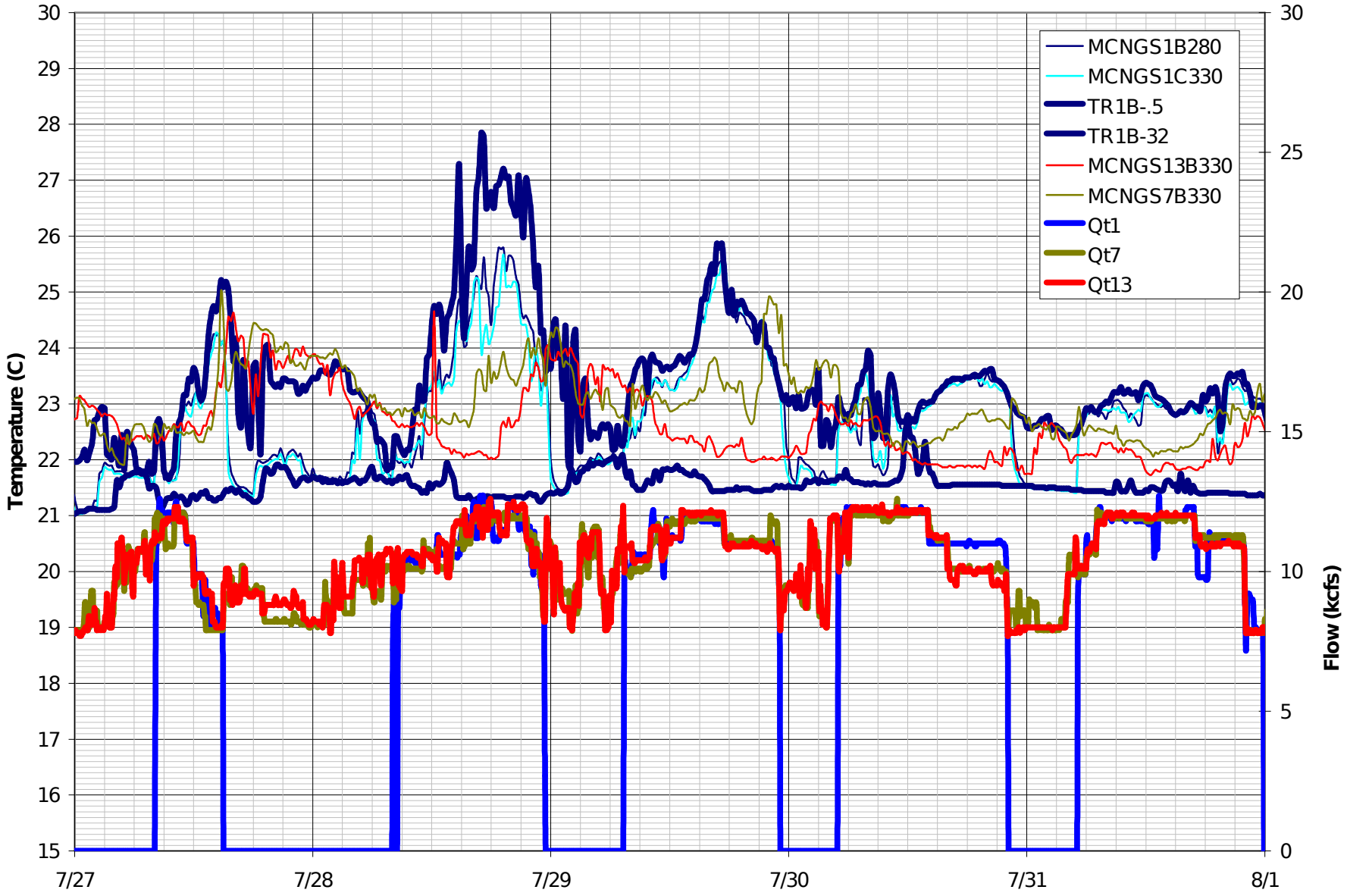
Temperature profiles in McNary Forebay on Transect T3 and at the lock guide wall (T4P6)
August 16, 2004 at 16:30 hrs

McNary Dam & Forebay Thermal Characterization 2004

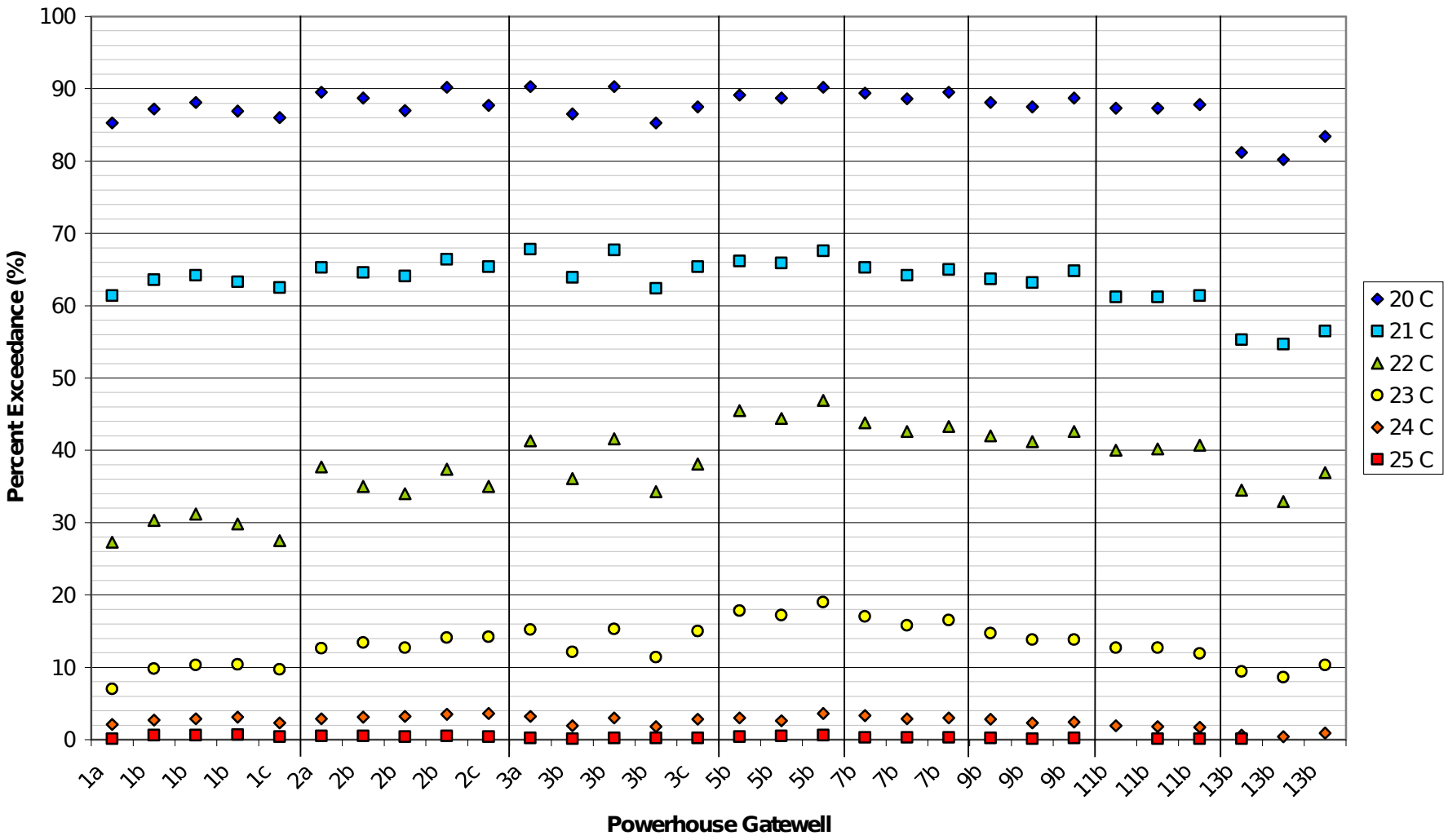
- Temperature Data Findings
  - Gatewells-(stratified forebay conditions result in elevated gatewell temps)
    - Temperatures can be significantly higher than average river conditions
    - Maximum Temperature >25 C
    - Duration of several hours
    - Warm forebay surface temperatures transported into gate well
      - » Variable response across turbines
    - Function of turbine operation
      - » Non-operating turbine draws water from lower one-third of water column
      - » Rapid change in water temperature during startup and closure
    - Tendency for units closest to south shore to experience higher temperature
    - No vertical temperature gradient in gatewell
    - Subtle thermal differences between slots A,B,C can occur



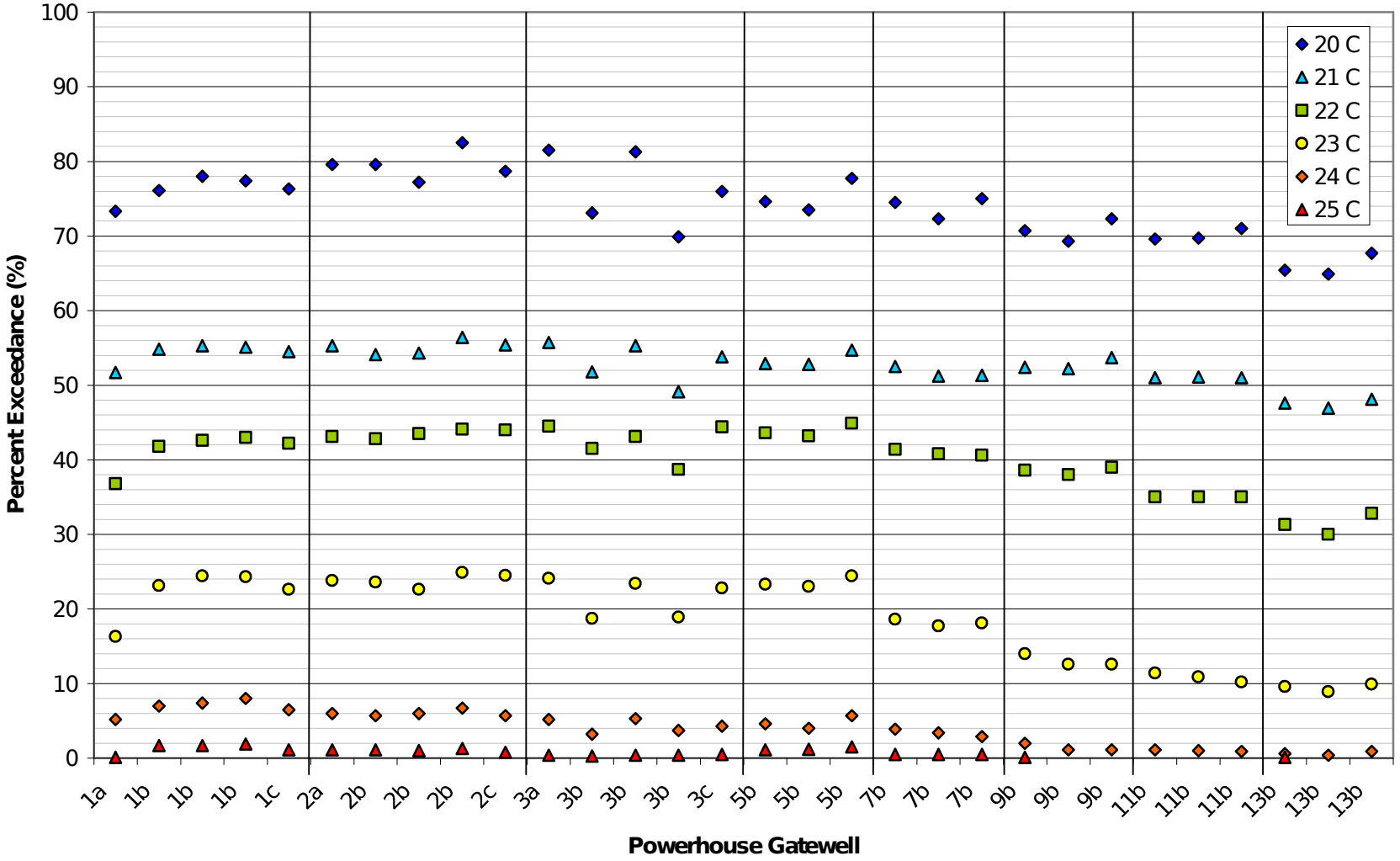
Time history of Powerhouse operations and gatewell temperatures
(Qt-Turbine flow, Nt=Number of operating turbines)



Time history of Powerhouse operations and gatewell temperatures
(Qt-Turbine flow, TR1B-Temp trashrack at 0.5/32 m)



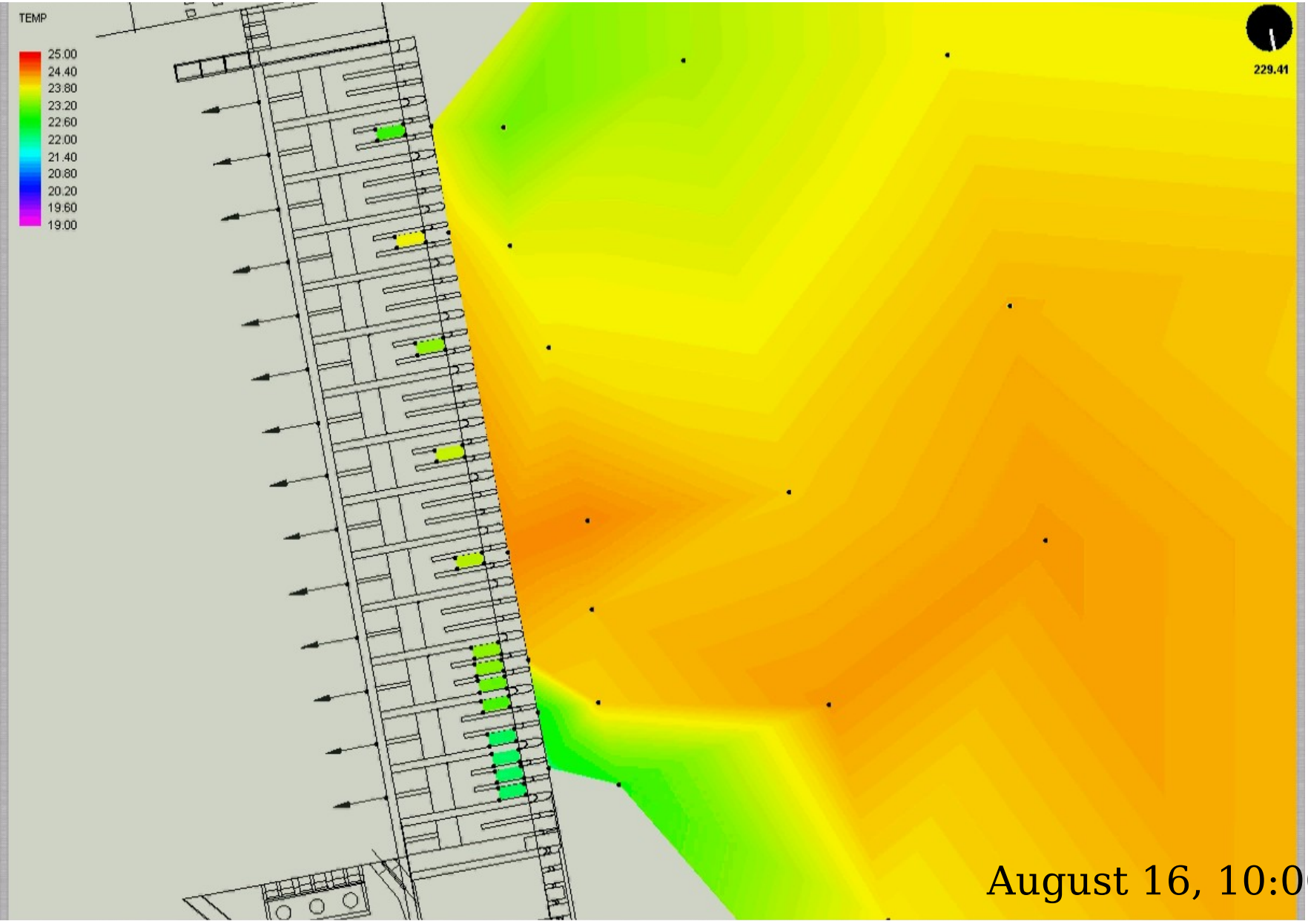
Statistical summary of gatewell temperatures at McNary Dam, 6/30-9/9 2004
(percent exceedance of temperature level)



Statistical summary of gatewell temperatures at McNary Dam, 6/30-8/31, 2004
(percent exceedance of temperature level for 14 unit operation only)

McNary Dam Thermal Characterization

- Development of surface water temperatures (0.5 m depth) in the Forebay of McNary Dam, August 16-17, 2004.
  - Sampling stations for temperature are indicated by black circles
    - Temperature contours generated by linear interpolation
  - Turbine discharge is reflected by vector length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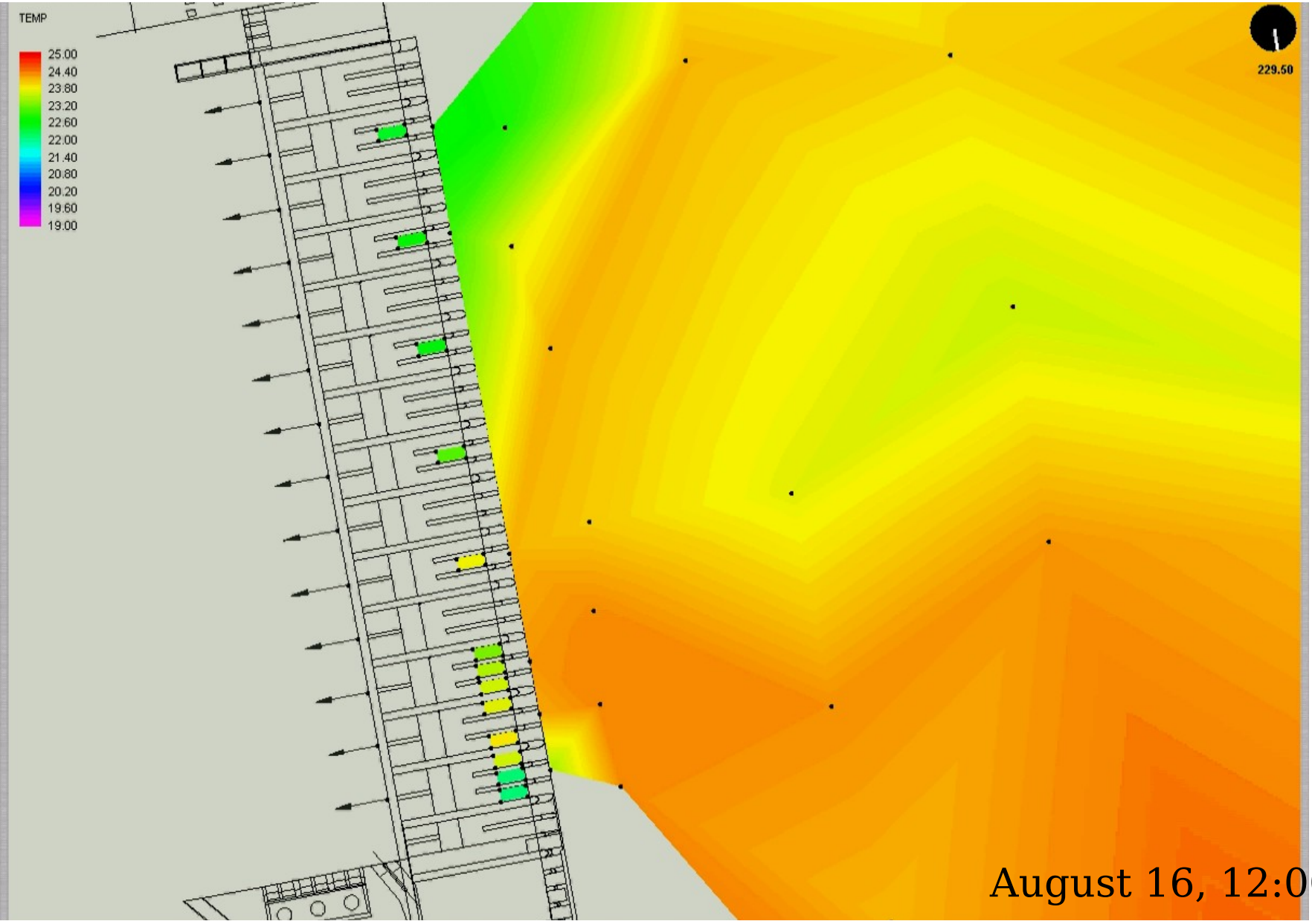
229.41
August 16, 10:00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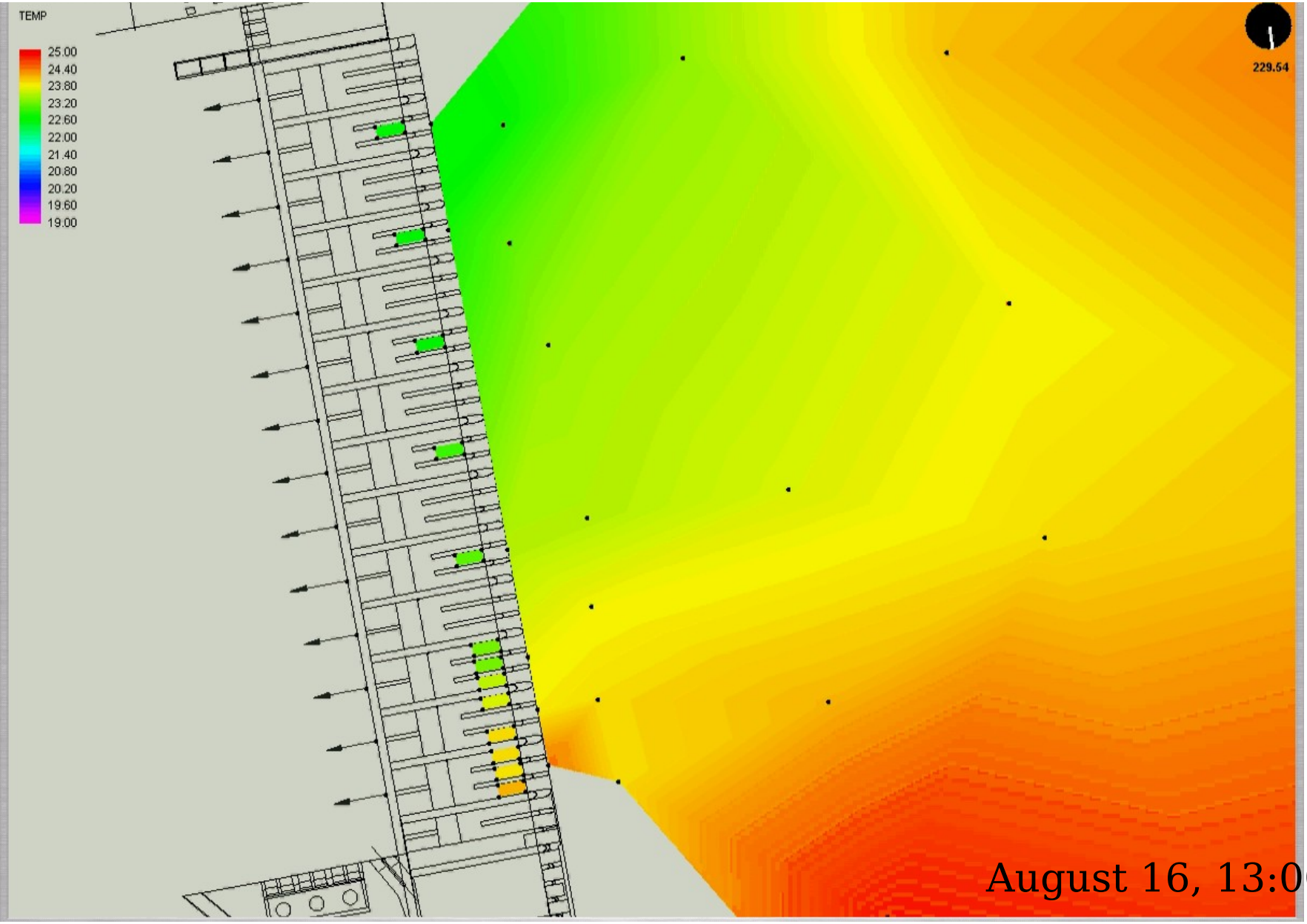
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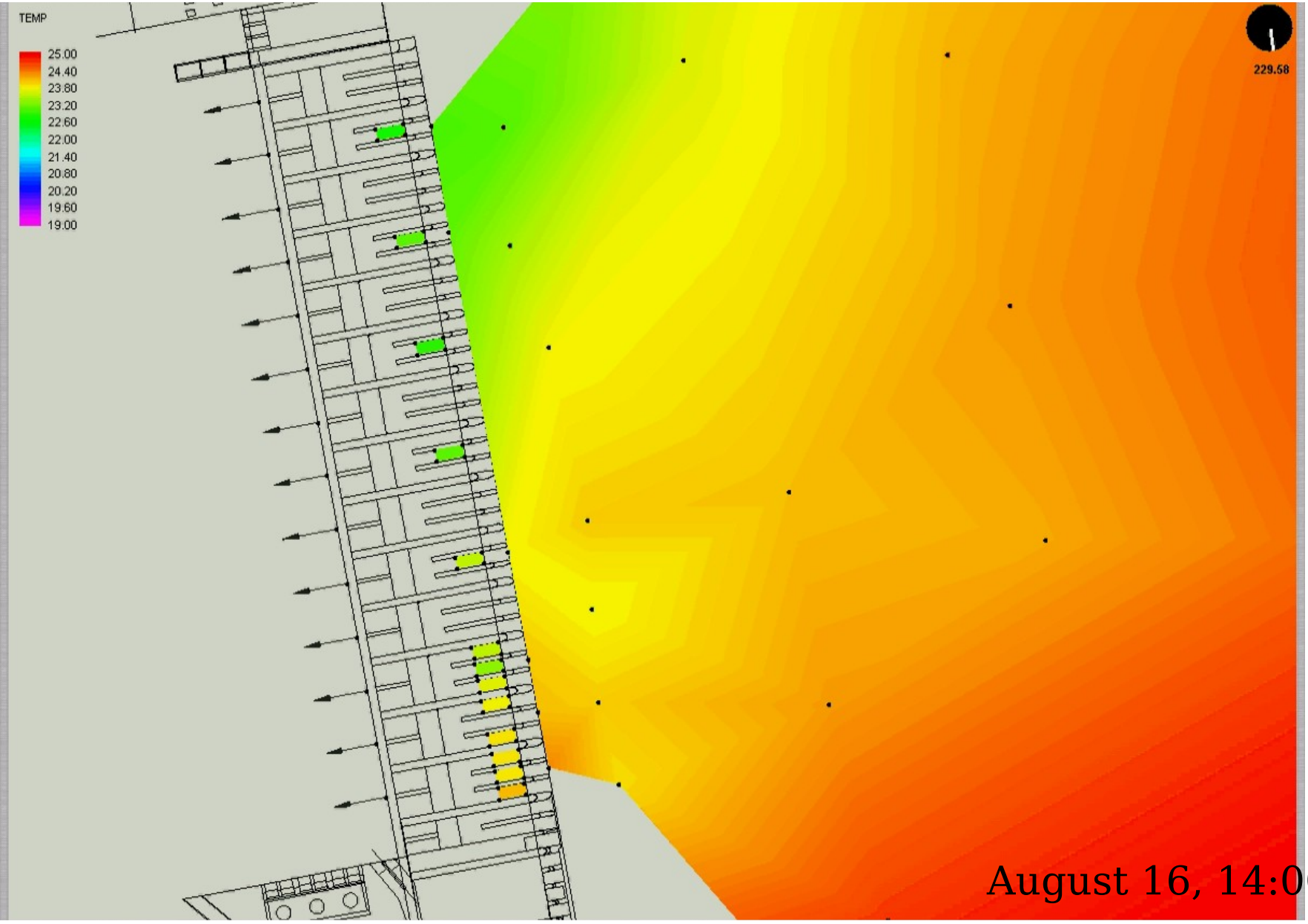
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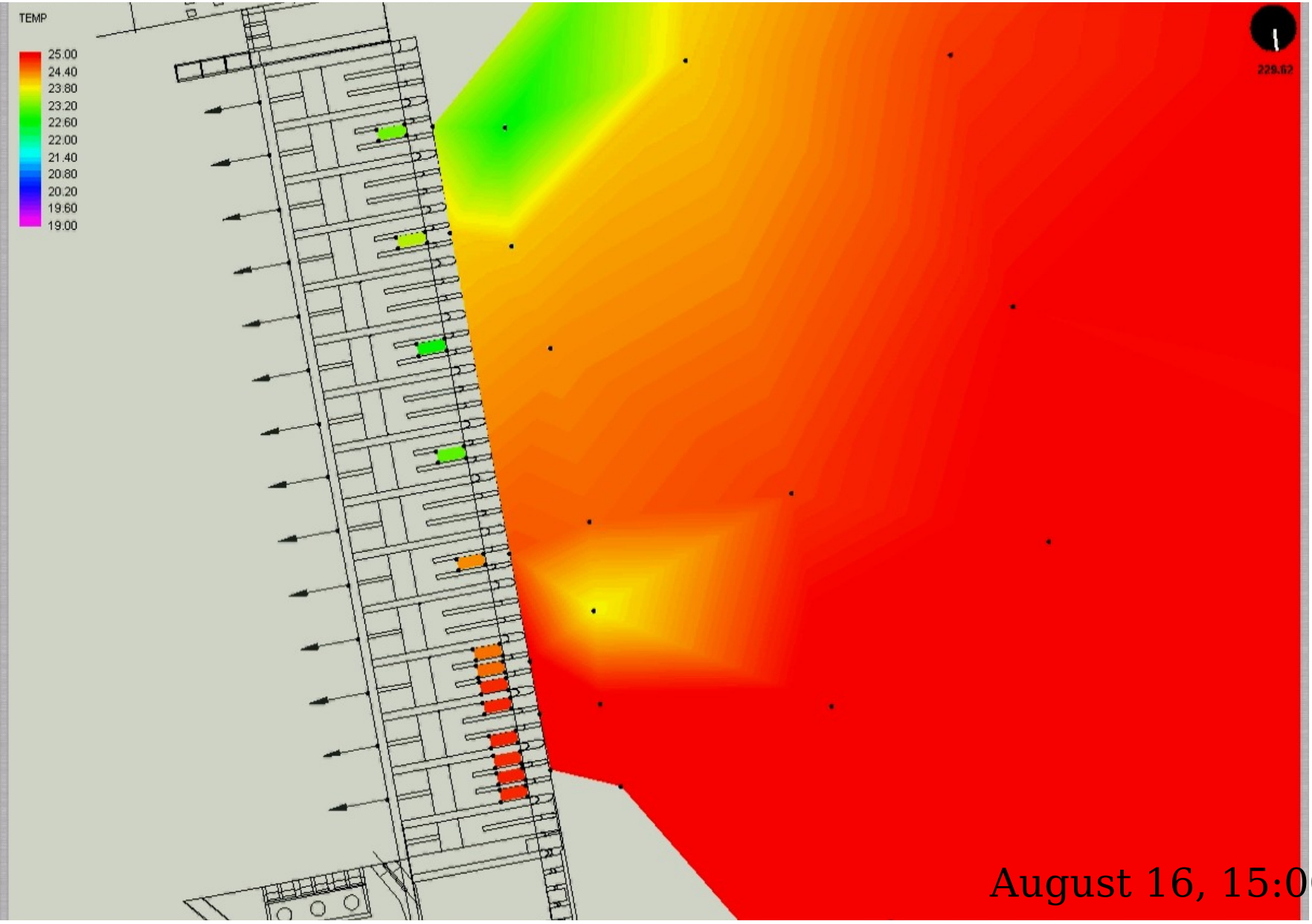
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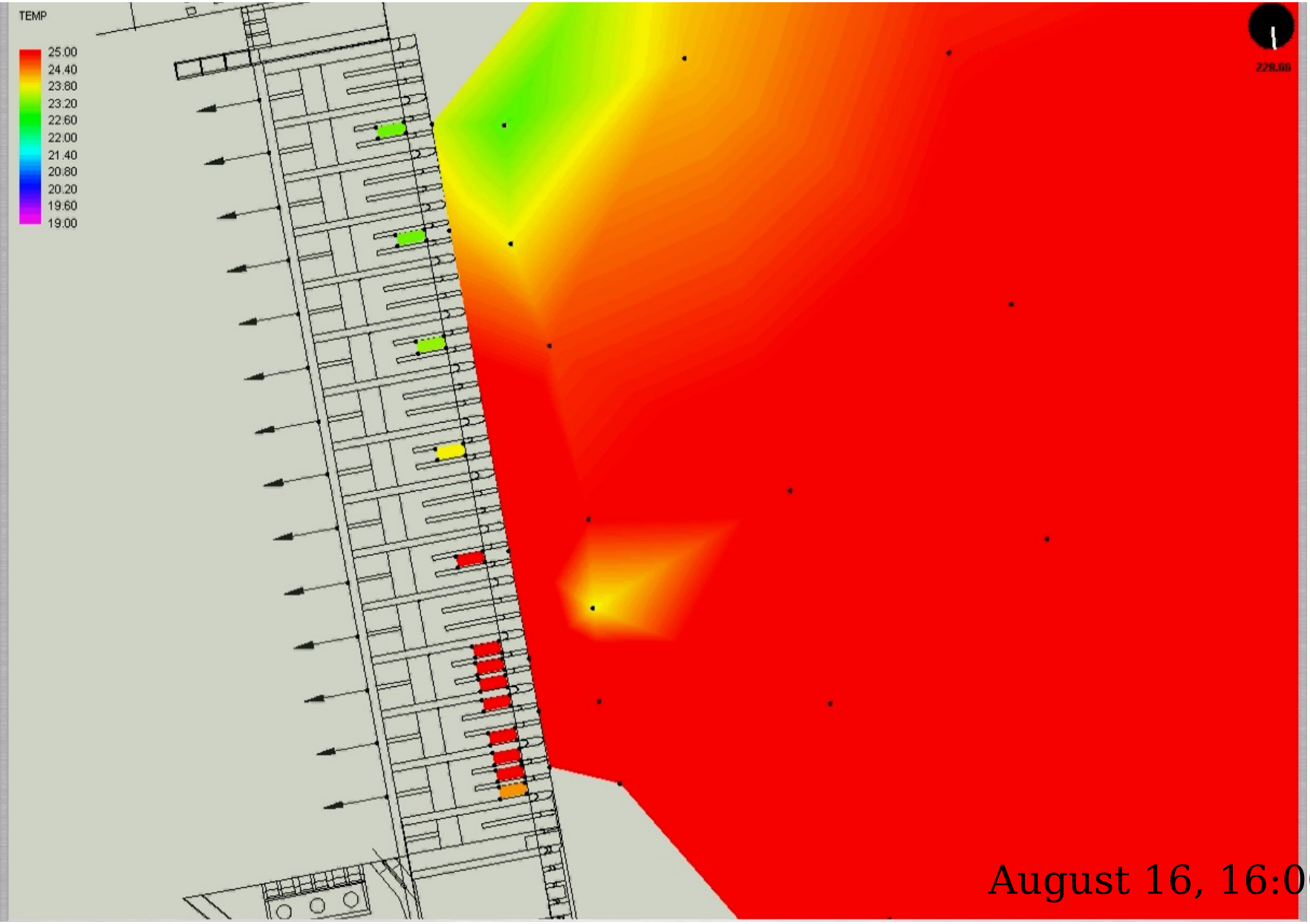
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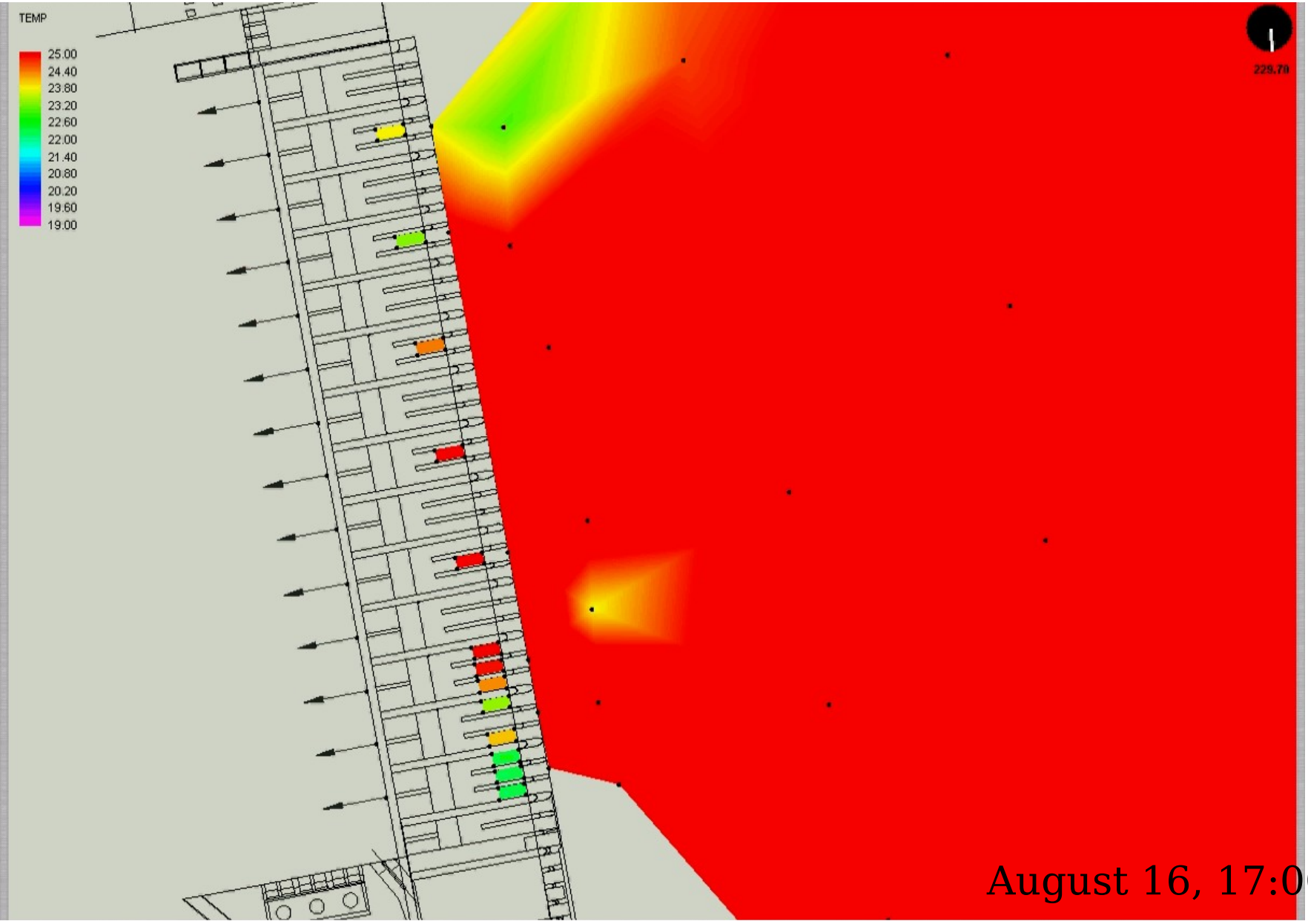
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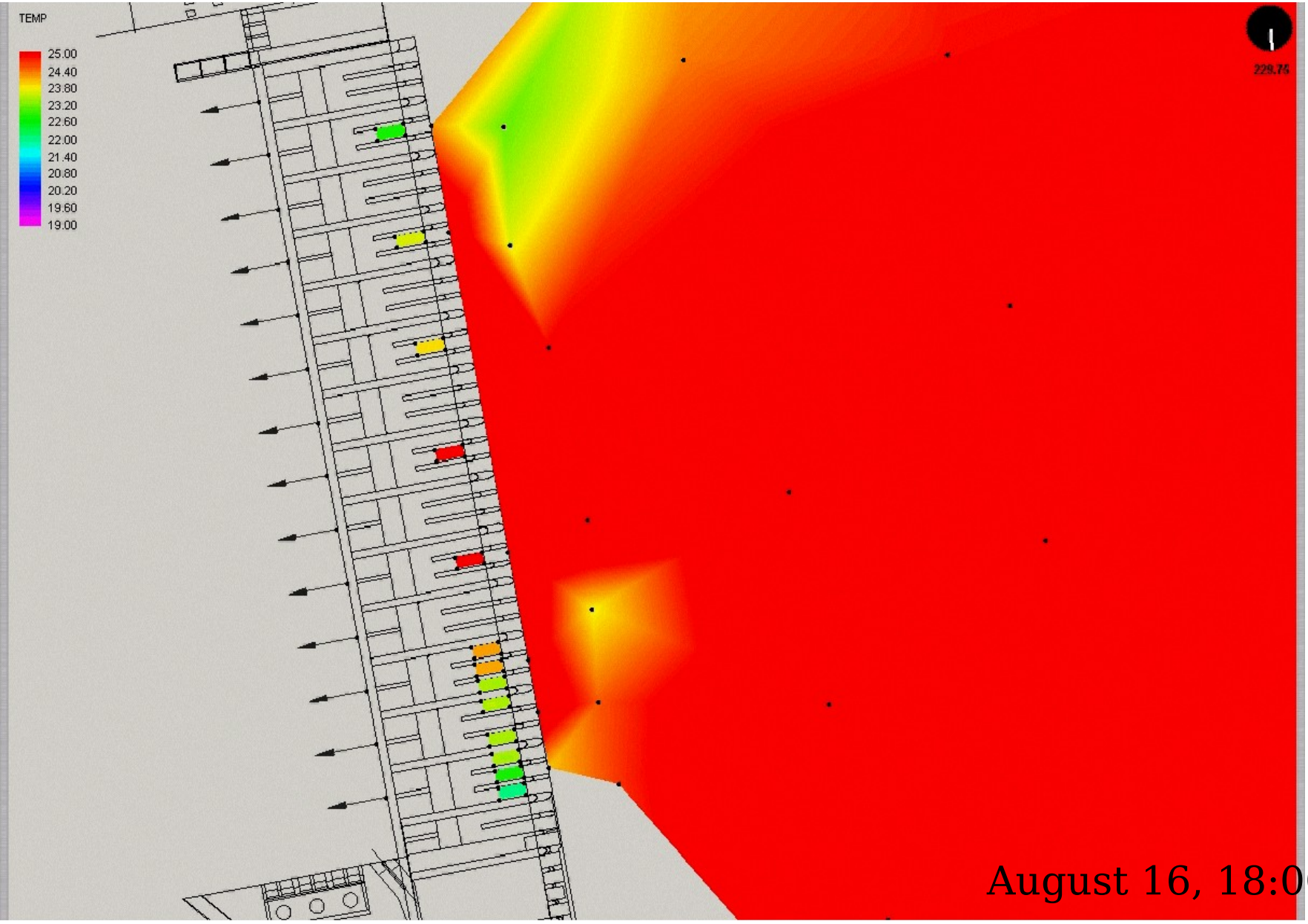
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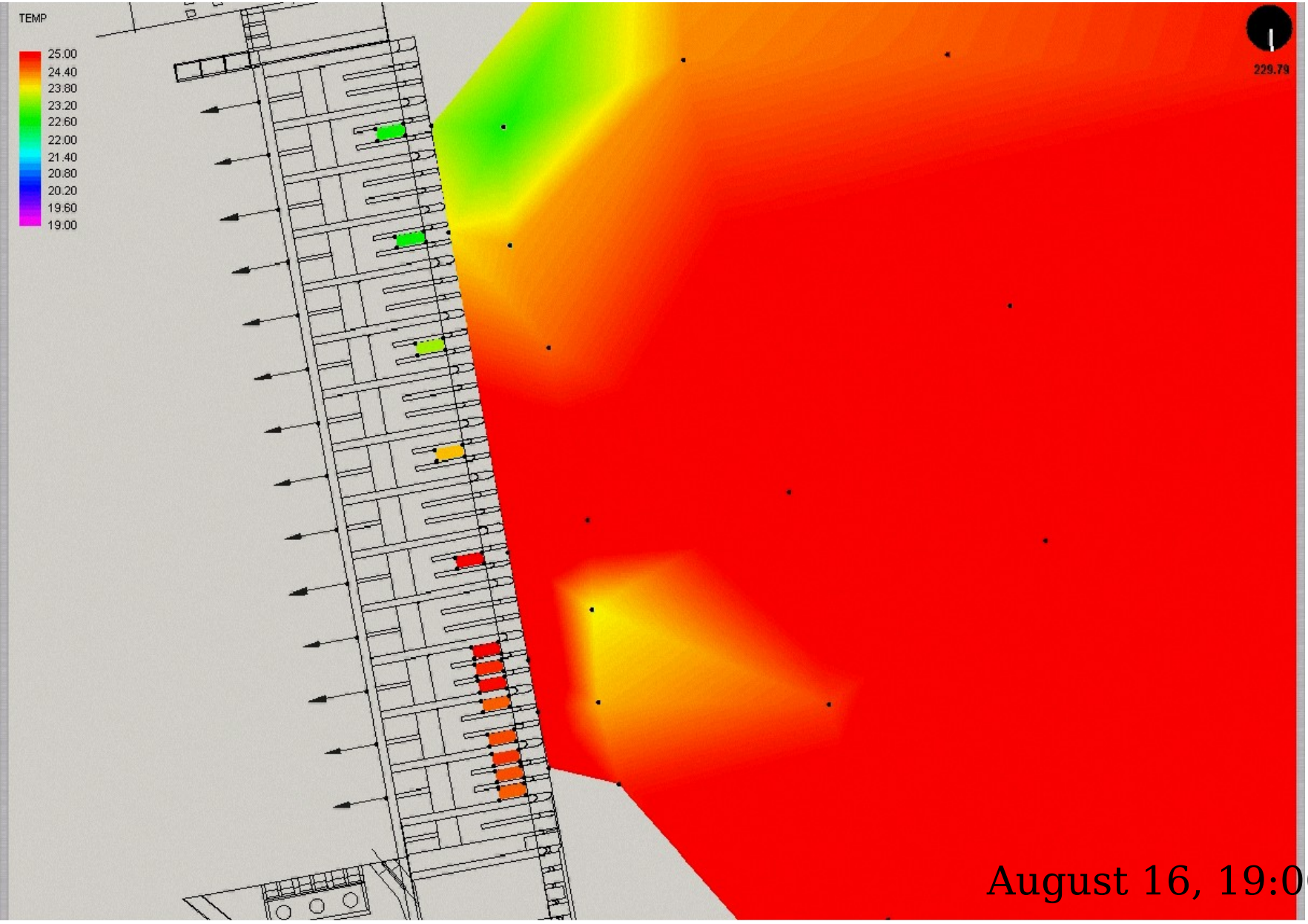
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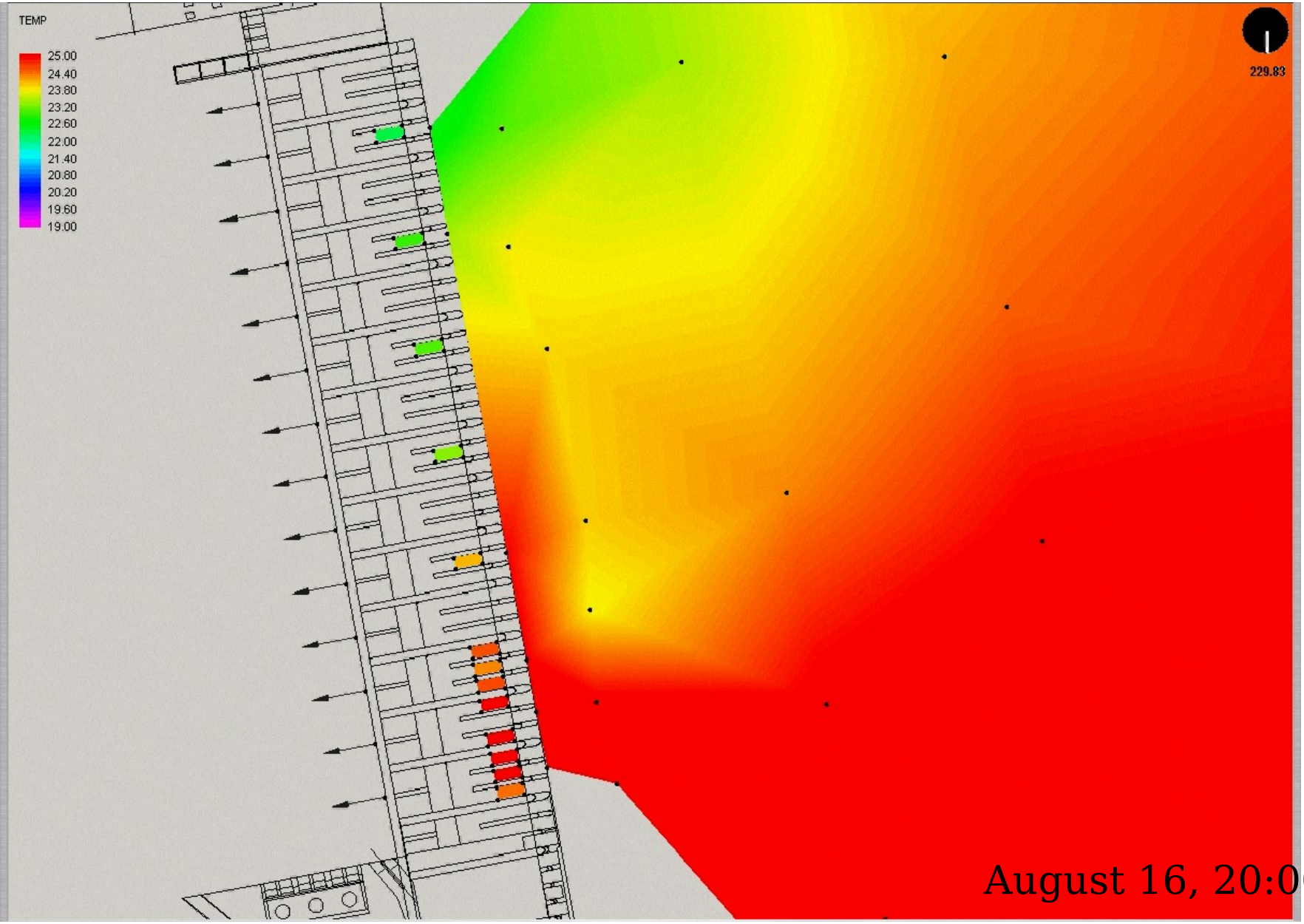
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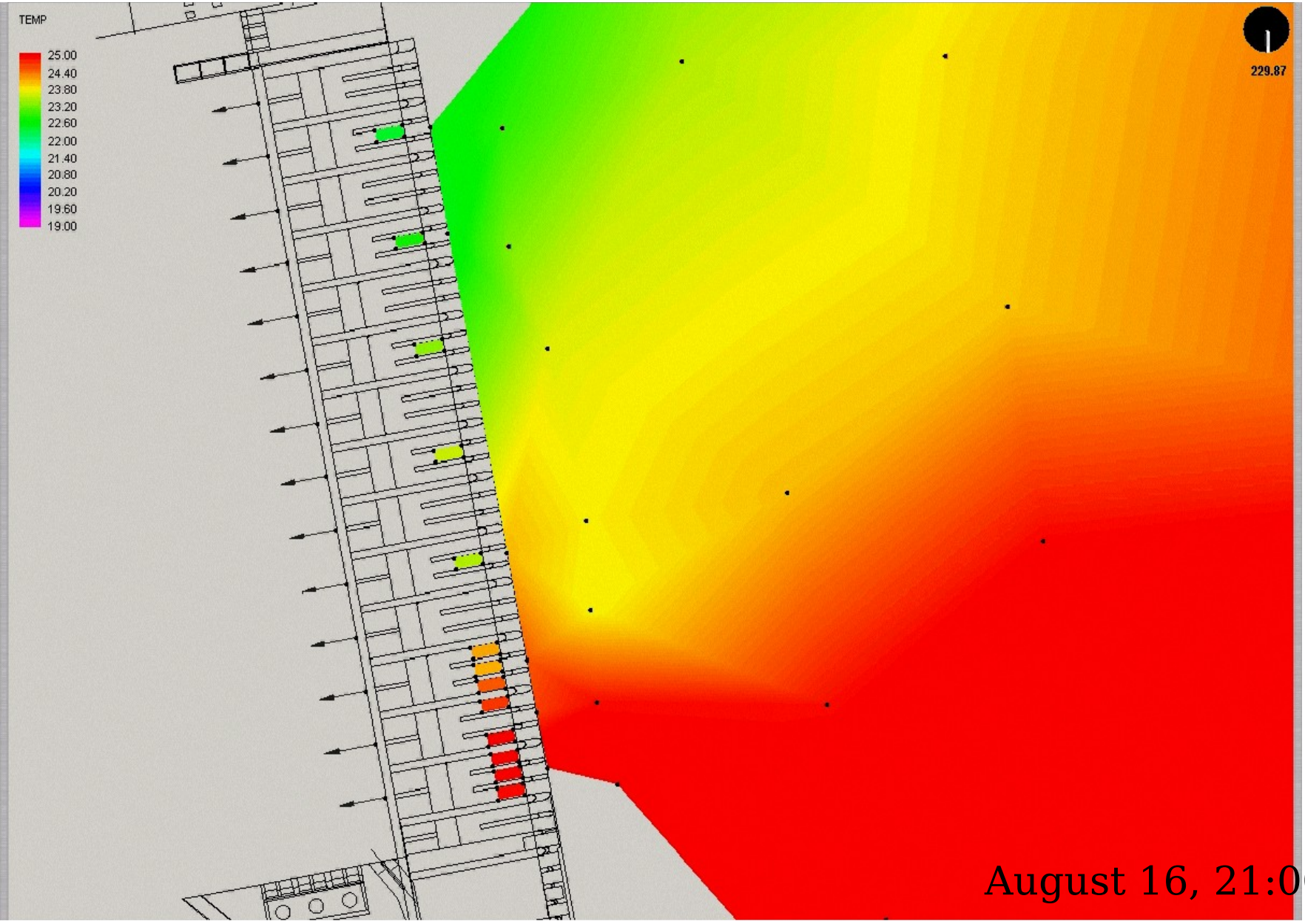
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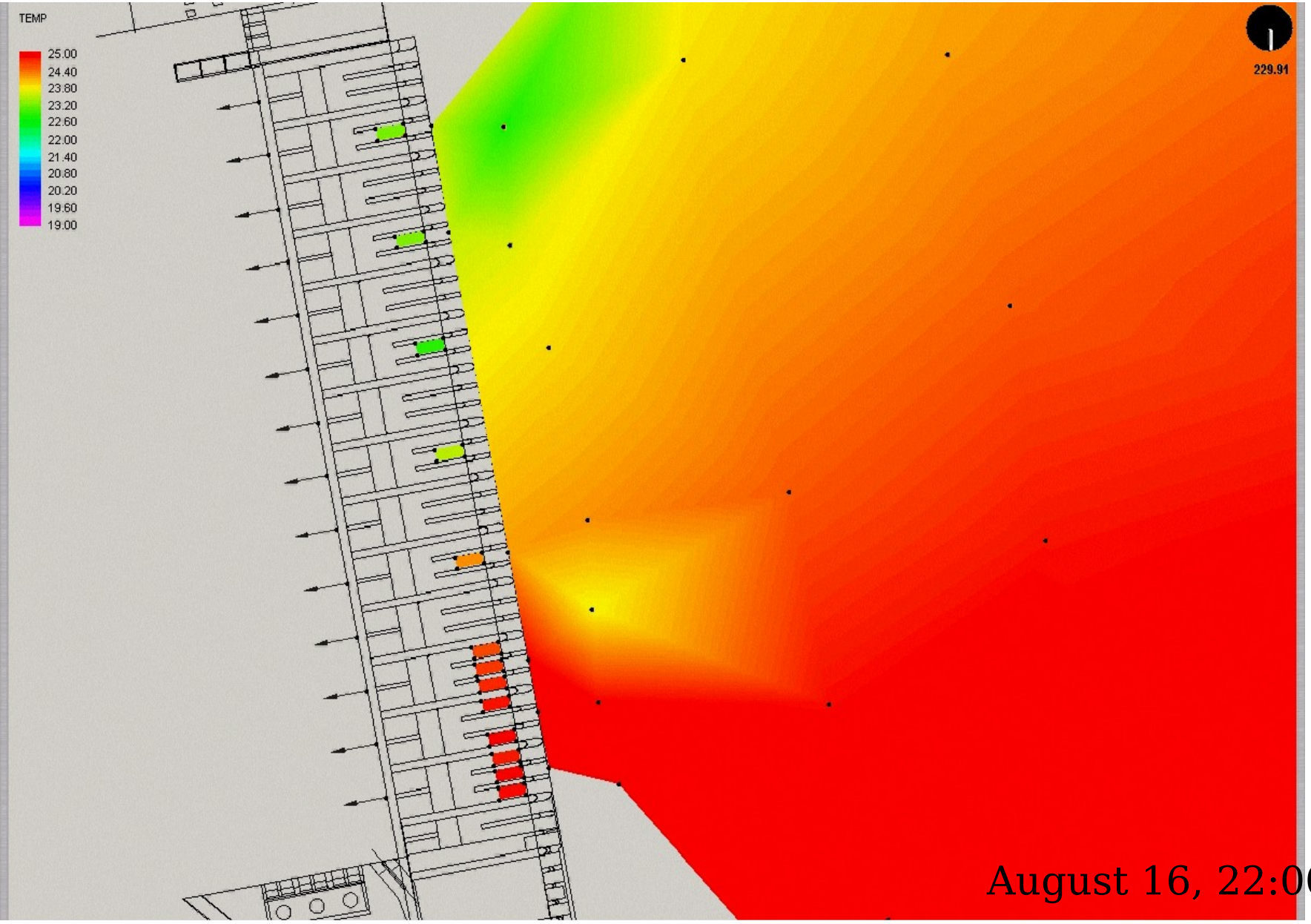
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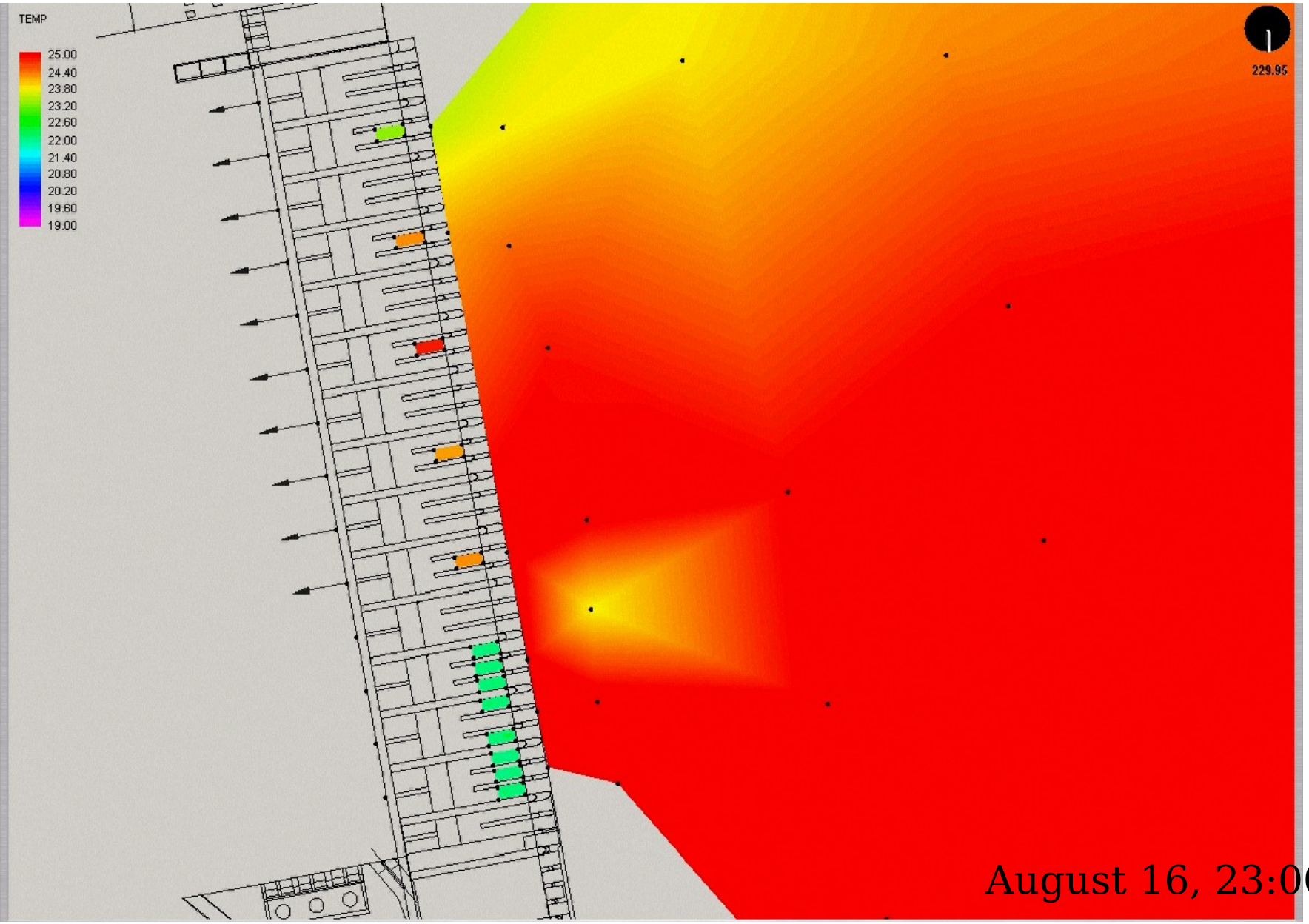
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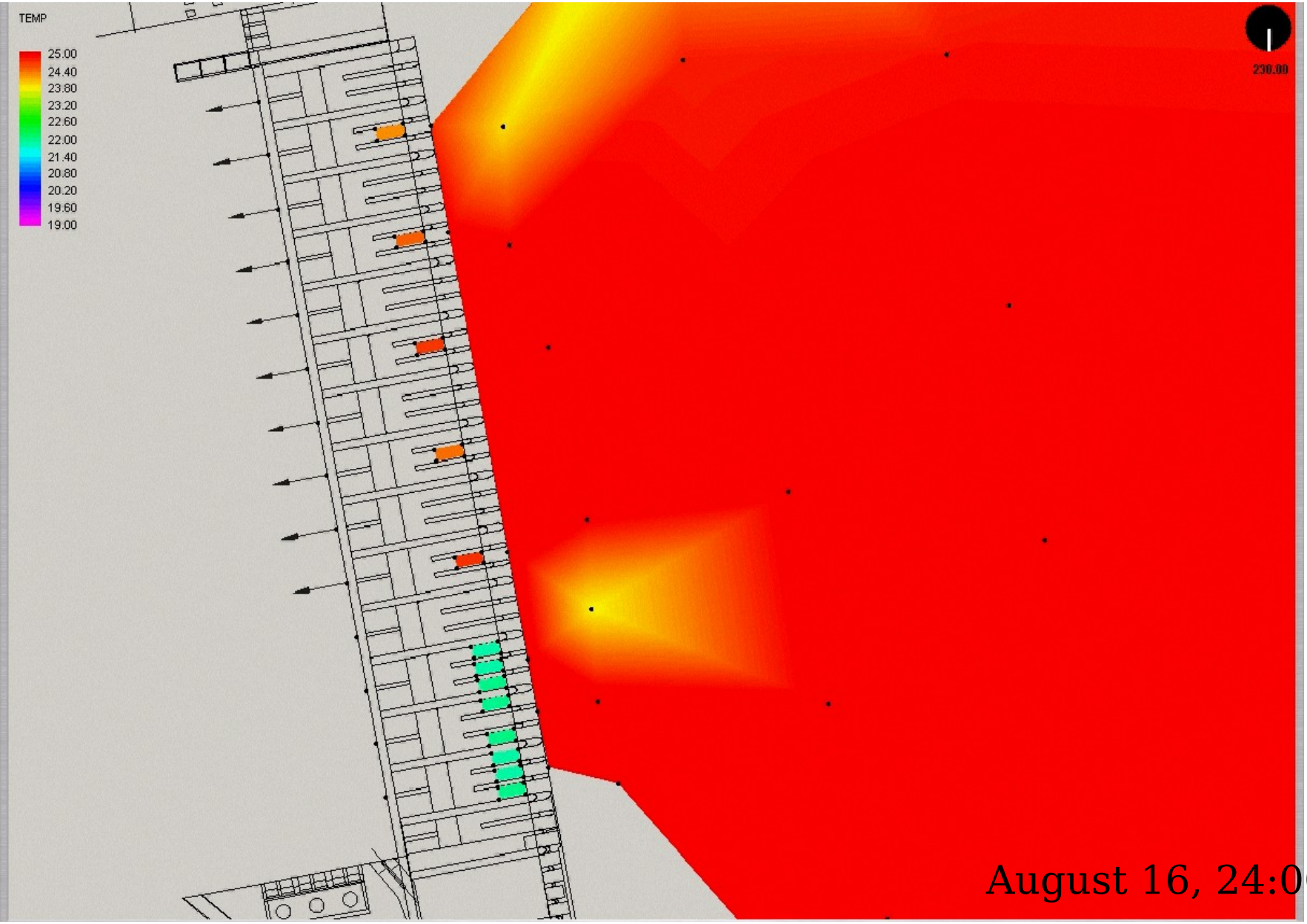
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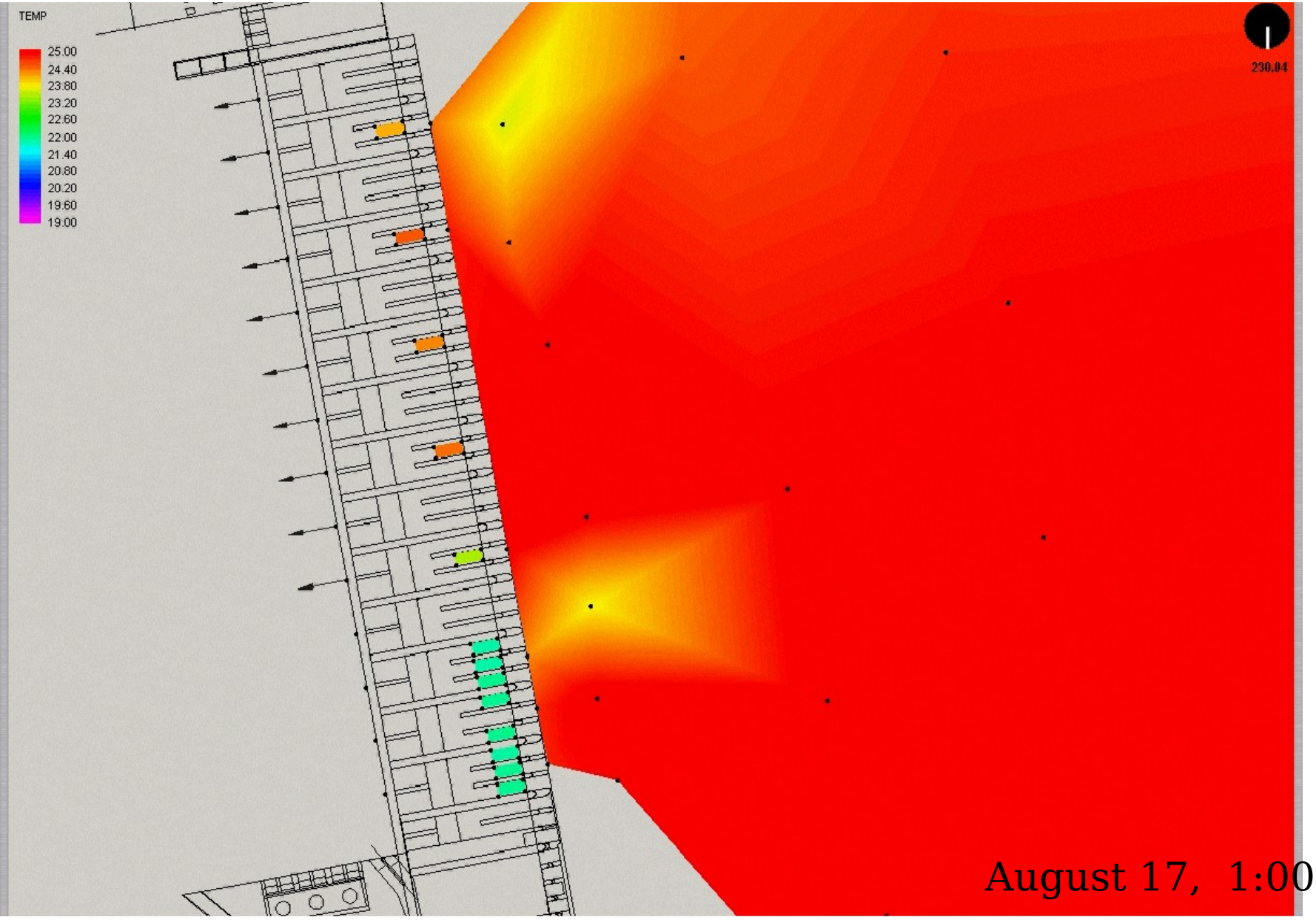
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August 17, 1:00

McNary Dam & Forebay Thermal Characterization
2004

- Temperature Management Alternatives
  - Monitoring
    - Early warning system in forebay
    - Gatewell thermistors
  - Operational
    - Number and location of operating turbines
      - 120 kcfs (10u x 12kcfs. 14u x 8.6kcfs)
    - Start up/closure schedule
      - Avoid 10-24 hrs
    - Daily load shaping during critical periods
      - Schedule non-capacity flows during late afternoon/evening hours

McNary Dam & Forebay Thermal Characterization
2004

- Temperature Management Alternatives
  - Structural
    - Selective withdrawal barrier
    - Mixing features
    - Provide supplemental water